SUPPLEMENT

TO THE

5th ANNUAL REPORT OF THE DEPARTMENT OF NAVAL SERVICE, FISHERIES BRANCH

CONTRIBUTIONS

TO

CANADIAN BIOLOGY

BEING STUDIES FROM THE

BIOLOGICAL STATIONS OF CANADA

1914-1915

THE BIOLOGICAL BOARD OF CANADA

OTTAWA
PRINTED BY J. DE L. TACHÉ, PRINTER TO THE KING'S MOST EXCELLENT MAJESTY.
1916.

CONTENTS

PREFACE.

By Prof. Edward E. Prince, LL.D., D.Sc., F.R.S.C., *Dominion Commissioner of Fisheries, Chairman of the Biological Board of Canada, Member of the British Science Guild, London, Vice-President International Fisheries Congress, Washington, D.C., 1907, Chairman of International Relations, American Fisheries Society, etc.*

A selection of the reports prepared by members of the scientific staff at the Biological Stations of Canada, on the Atlantic and Pacific coasts, is now presented as an appendix to the 5th annual report of the Naval Service Department, Fisheries' Branch.

Of the seventeen papers, seven of them are zoological, and have a direct practical bearing upon the fisheries. Four of them relate to fish culture, especially lobster, oyster and shellfish culture generally. Two of them are of a botanical and chemical character, and have special reference to the utilization of important seaweed resources, which yield chemical products of extreme value. One report describes a disease, epidemic in fishes, and adds another to the series of papers on fish epidemics which have appeared in previous volumes of "Contributions to Canadian Biology." Three of the papers are hydrographic and physical, and comprise researches which must be regarded as preliminary to surveys of the fishing areas to which they have special reference.

It is not necessary to point out that the Biological Stations, maintained by the Dominion Government, must prove of great benefit to the fishing industries, nor to affirm that university students, and members of the staffs of the various universities in the Dominion, have unequalled opportunities now afforded for carrying on the highest researches into the life of the sea, which formerly were supplied only by foreign Biological Stations. The opportunity is being taken advantage of more and more as the years advance, and during the last season or two the tables at the Marine Biological Stations of Canada have been fully occupied, and the laboratories at times have been somewhat overcrowded. There is a growing desire on the part of the biologists, both junior investigators and senior members of university staffs, to aid in contributing to our knowledge of the valuable fishery and other resources of our prolific Dominion waters.

Apart from the work actually carried on at the stations, the Biological Board entered upon an investigation in 1914 of a very special character, namely, the herring fisheries of the gulf of St. Lawrence and the Atlantic coast of Canada generally. An eminent expert, Dr. Johan Hjort, Director of Fisheries, Norway, consented to conduct an elaborate series of researches with the aid of a staff of trained Canadian biologists. The parliamentary vote provided annually for the purposes of the Biological Stations was wholly insufficient to meet the expenditures involved in this extensive herring scheme, and a special appropriation, with the consent of the Honourable the Minister, was generously provided, which assisted materially in enabling the Biological Board to carry through the researches successfully. Professor Willey, McGill University, Montreal; Dr. A. G. Huntsman, University of Toronto, Toronto; Professor J. W. Mavor, University of Wisconsin, Madison; Dr. Bjerkan, of Bergen, Norway, and others, assisted Dr. Hjort, and a preliminary report was completed, and issued early this year, to be followed by a more elaborate and detailed report which will be issued in the course of a few months. The board has been indebted, in connection with this work, to the University of Toronto for the use of laboratories, and assistance by various members of the university staff, and to Principal Sexton, Halifax Technical College, Nova Scotia, the Biological Board was also indebted for many courtesies.

The Minister of Naval Service, the Hon. J. D. Hazen, took very great personal interest in this important work, which has aroused unusual interest amongst the leading men engaged in the fisheries all along the Atlantic coast of the Dominion.

It has been suggested, in order to facilitate reference to the papers comprising the present volume, that a brief popular resumé of the chief points set forth in these papers should form the preface by the chairman of the board. I have therefore summarized some of the principal features in the seventeen papers which follow, and in this summary I follow the order of the papers seratim.

I.—PACIFIC HALIBUT FISHERIES (PROF. WILLEY).

Professor Willey in his report on "The Pacific Halibut Fisheries," after describing the Indian methods of fishing, lays stress on the lack of information upon the spawning peculiarities and habits of the halibut generally, although the evidence seems to indicate that the fish deposits its eggs, probably during the winter, on the Pacific coast. The eggs of the halibut were described by Mr. E. W. Holt, and Professor W. C. McIntosh, in 1892, and are large, transparent eggs 1/7 inch in diameter, destitute of an oil-globule and, without doubt, very buoyant. Dr. Willey ventures the opinion that halibut eggs do not float near the surface, but are most probably bathypelagic. The deep-sea argentine, a fish allied to the smelt, produces a bathypelagic egg about the same size as the halibut's egg, and they occur in water layers at great depths. The larva, on hatching out, measures 7·7 mm., but small specimens have been obtained in the sea measuring 10¼ mm., while one of 28 mm. has been taken at a depth of over 270 fathoms, and another specimen 50 mm. long was taken in water of over 550 fathoms. The striking correspondence in size, etc., as Dr. Willey points out, indicates that the halibut has probably a bathypelagic egg. A concise narrative follows of a three and a half months' expedition around Queen Charlotte islands, Goose island, the Alaskan shores, and other halibut grounds. The fish captured fall into three classes: chicken halibut (20 to 29 inches long), medium (30 to 39 inches), and large halibut (40 inches and upwards). The size varies with the age, and a 28-inch fish is probably eleven years old. The migrations from the shallows (15 fathoms) where it feeds), to greater depths of 150 fathoms, where it probably spawns, appear to be the main movements, rather than extensive north-and-south migrations.

There is urgent need of more statistical information, and detailed records of halibut captures, and of international co-operation, so that a recognized basis may be established for restrictions, if necessary, although the aggregate catches on the banks show no signs of permanent exhaustion. Indeed the thinning out of the banks may improve the quality of the supplies of fish that remain. In view of the success of plaice hatching, Dr. Willey favours experimental halibut hatching operations. Towards the close of his report, Dr. Willey points out the terrible waste of good food fish captured by the halibut boats but thrown away because inferior to the halibut in commercial value.

II.—THE EGG OF THE HALIBUT, ETC. (PROF. PRINCE).

The second report, which is by myself, on "The Egg of the Halibut, etc.," gives in detail the more important observations on the features of the halibut eggs so far as known. The ripe, unfertilized eggs obtained by Professor McIntosh at the Scottish Marine Laboratory at St. Andrews, and Mr. E. W. L. Holt's account, and Dr. H. C. Williamson's description of the ripe eggs (especially the double envelope described by the latter author), are first referred to, and it is pointed out that the spawning season of halibut, in Europe, extends over many months, from January to May. Dr. Gilpin found in Nova Scotia ripe "running" fish in June, but the fertilized ovum has not yet been studied by any expert. The young larval halibut are then described, includ-

ing various doubtful specimens obtained in the North sea and North Atlantic. The smallest specimens, wormlike in form, range from ½ inch to ⅝ inch in length, and when pigment appears, it forms four indefinite rows of black spots along the body, on each side, and extends over the median unpaired fins. The flattened form is gradually assumed, and when the length of 1 inch in reached, coloured cross bands, seven in number, appear on the two large median fin-expansions. Dr. Schmidt, the Danish biologist, obtained specimens of the last-named size in 60 fathoms in the month of May. The fish at 34 mm. (1⅓ inch) though still more flattened, continue to swim on edge, and on the right side the dark colour is more pronounced. A mottled arrangement of colour is soon assumed, and this is a feature which is characteristic of the halibut during post-larval life. At the length of 5 inches the full-grown features are assumed, and specimens of that size were obtained by Professor Verrill in the straits of Canso, and Scottish specimens, 12 inches in length, are recorded by Professor McIntosh on the east coast of Scotland; and halibut rather smaller (10 inches long) are common in shallow waters around Iceland. Dr. Wemyss Fulton is of the opinion that small halibut move into deep water in the late summer, and in October he obtained Scottish specimens, 17½ to 30 inches long, at a depth of 65 fathoms.

The less common species of halibut (*Hippoglossus hippoglossoides,* Walb.) is distinguished in its youngest stages by lack of colour, and when ½ inch long is still very sparingly spotted, in contrast to the familiar species *H. hippoglossus.*

III.—BRITISH COLUMBIA KELP BEDS (PROF. A. T. CAMERON).

The third report on " The Kelp Beds of British Columbia," by Professor Cameron, Winnipeg, presents an account of an important research, treating specially of the two most valuable species, the bull-kelp and the sea-ivy, or long bladder kelp. These two species of Laminaria are commercially valuable as they yield more potash than Fuci and other rock-weeds, and can be more easily harvested. The former, the bull-kelp, occurs all round the British Columbia coast, but the latter, the sea-ivy or flag-weed, is absent in regions where the water is of diminished salinity. Both require a rocky shore for firm attachment, and a tidal flow, three to five knots per hour, a salinity not less than two-thirds ocean salinity (mean density, 1·019), and a suitable temperature.

The bull-kelp grows in spring, but decays rapidly after July, the crop being thickest from July to October. The beds are visible, however, all the year, as new plants attain some size before the old plants die. They spread asexually by spores. Possibly in late July, harvesting of the beds should commence, after the spores have been discharged.

The sea-ivy has a life longer than a year, and spores are produced on fronds towards the base or root, and the species can thus be more readily harvested than the bull-kelp.

Dr. Cameron estimates the extent of available Pacific beds, and indicates their location on a map specially prepared by him. He describes as " thick beds " those on which there is at least one plant to a square yard; though there may be three, four, or more. The portions commercially available in each plant range from 5 to 8 pounds to 24 pounds, the average being about 12 pounds per plant, and one mile of coast line should yield 245 tons, or a total British Columbia harvest annually of considerably more than 400,000 tons of kelp. Some areas are more productive than others. On Queen Charlotte islands, each plant would yield 15 to 20 pounds of raw material. The amount of water in the tissues of kelp is, of course, large, namely, 92 per cent, in the fronds, with 8 per cent dry matter; the stock, 87⅜; and 12⅝ dry matter; root or hold-fast, 87½ and 12½ dry matter. The air-bladder contains 94 per cent of water and only 6 per cent dry matter. Assuming that the potassium chloride is 30 per cent and valued at $50 per ton, and the iodine ·12 per cent and valued at $38.75, the total value per annum would, for the former, be $11,750,000, and for the latter $3,680,000, or a total

of $15,000,000. Possibly some districts, as the author points out, could not be readily exploited at present, but large areas are certainly available for profitable utilization. Further experiments are urgently needed, and a scheme of leasing and of turning the kelp-beds to account might be advantageously devised without delay.

IV.—GOVERNMENT LOBSTER POND, N.S. (PROFESSOR KNIGHT).

The problem of impounding breeding lobsters, hatching them out and rearing the fry, in inclosed waters, form the main subjects of Professor Knight's laborious "Researches at the Lobster Pond, Long Beach, Digby Neck, N.S." His results are difficult to summarize, but the conclusions reached are that an ideal lobster pond should be—

(1) Accessible for easy transportation of lobsters and fry.
(2) Of a temperature appropriate, and not too cold.
(3) Of a suitable depth.
(4) Not subject to excessive vegetable growths, diatoms, etc.
(5) Open to ample sunshine influence.
(6) Provided with sheltered areas.
(7) Of suitable salinity.

The last two conditions only are satisfactorily provided at Long Beach. According to Dr. Knight's investigations, the average temperature it appears was 60·8° F., and far too cold for the growth of lobster fry, which became clothed with parasitic plant growths during their retarded development, and in consequence unable to feed properly, so that they died before reaching the fourth stage. The fourth stage is usually attained in the second or third week, when the larval features are lost and the fry descend to the bottom. In addition to the coldness of the water, cloudy weather, and microbes, all affecting the delicate young fry, there appeared vast numbers of shrimp-like enemies (*Mysis idotea*), etc. One specimen of *Mysis* was placed in a basin of water with ten lobster larvæ, and in two hours eight were killed and partly devoured.

Dr. Knight confined a number of male and female lobsters in limited inclosures, and found that 70 per cent of the females extruded eggs before the end of September, in contrast to the conditions in the open sea where a large number of female lobsters never find males; hence the small percentage of females found by fishermen carrying eggs in St. Mary's bay and the bay of Fundy. The sexes are too widely scattered, and Dr. Knight lays emphasis on the necessity of providing inclosed mating grounds under official superintendence. The details of the rearing plant and the machinery used are included in the report and are of considerable interest. The Long Beach pound in most respects does not appear to be favourable for the objects sought by the department.

V.—BARREN OYSTER BOTTOMS, P.E.I. (MR. A. D. ROBERTSON).

Mr. A. D. Robertson's report on "Barren Oyster Beds, P.E.I.," indicates the large amount of investigation desirable in order to ascertain the possibilities of expanding oyster culture. The bottom of these "barren areas" was found to be red sand, with rocky sandstone patches and soft mud, while in some places dense layers of oyster and clam shells covered the soft portions. Eel grass occurred from a depth of 8 to 12 feet out from shore, and seaweeds usually clothed the rocky surfaces. The channels, 2 to 30 or even 40 feet, frequently presented abrupt edges on which oyster spat settled. Salinities and temperatures were taken at 126 places, both at the top and bottom of the water, and specific gravity, percentage of chlorine and of solids were the features ascertained. The densities are most suitable for oyster growth. The floating food diatoms, etc.) was studied, and samples submitted to Dr. A. H. MacKay, of Halifax,

for later report. There is an outflow over the oyster areas of fresh water in spring, but it is inconsiderable during the summer. Mr. Robertson calls attention to the abundance of enemies of the oyster, such as starfish, the drill (*Urosalpinx*), limpets, boring sponges (*Cliona*), while frost and ice are very detrimental. Poaching is frequent, and a very serious menace. The areas were formerly productive, as is seen from the extensive beds of dead shells remaining. Spat collectors were erected in August, consisting of shells held in place by upright wire cylinders, but the deposit of spat was light, though it occurred in all parts of Richmond bay. Spatting was late in 1914, and oyster fry were observed from August 1 to the 29th, but not later. The "set" was best in the shallows warmed by the sun, and free from eel grass.

The general conclusion reached is that the oyster beds are in bad shape, owing less to unfavourable physical conditions than to over-fishing.

It is necessary—

(1) To enforce proper laws.

(2) To carry out a three years' close season.

(3) Lease spatting grounds to fishermen out from shore to a depth of 4 feet.

VI.—SUPPOSED DISEASE OF QUAHAUGS IN N.B. (PROF P. COX).

Professor Cox, of Fredericton, N.B., contributes three papers embodying researches carried on as a member of the staff of the station. His first report, No. VI, on "A Supposed Disease of the Quahaug (*Venus mercenaria*)," aimed to determine the cause of a deterioration in this valuable shellfish, observed by the shippers when transporting them to Chicago and other markets from Buctouche, N.B. Dr. Cox gives a full account of the conditions on the beds and the methods of fishing, and describes the storing of the shellfish in floating trays 14 by 18 feet and 18 inches deep, which trays are filled to a depth of 6 inches to 18 inches with quahaugs, and often stored for a period of several months. They are then packed in sacks of 1½ bushels capacity, and shipped in box cars, which are iced at each end. The temperature is probably 68° to 70° F. in the winter (and lowered to 45° to 50° F. in the cars), and then on reaching Chicago they are probably exposed to a temperature of 80° or upwards. These changes of temperature, and the lack of ventilation during shipment, must be detrimental, and many do not survive these extreme conditions.

To test the effect of these sudden changes, eight clams were put in the ice-house at the station for three days, the temperature being 45° to 48° F., and then exposed to the open air at 60°, or in one instance 70° F. At the end of three days, all were dead, excepting one. In another lot of ten, taken from the trays and exposed to the open air for fourteen days, it was found that all survived. A number of other interesting experiments are detailed in the report, and Dr. Cox suggests that possibly a percentage of adult clams normally die each year after the breeding season. He suggests avoidance of rough handling, securing of proper ventilation, and uniformity of temperature. The deterioration and death of clams are in his opinion not due to disease, but to unfavourable conditions; and the paper closes with some practical suggestions for shippers, and with the statement of four biological problems which still await investigation respecting the quahaug industry.

VII.—HERRING DISEASE (PROF. P. COX).

A very important investigation carried on by Professor Cox forms the subject of report No. VII, namely, the "Disease of the Herring in the Gulf of St. Lawrence in 1914." There was an epidemic amongst the herring, which resulted in great mortality from the middle of June to about the middle of July.

In 1913 a similar epidemic was observed; vast numbers of dead and dying fish being noticed in June by the fishermen, before the annual run of spawning herring had left the coast. Fishermen recalled a similar condition sixteen years ago. The herring affected appeared to be the oceanic form, which visits Northumberland strait in July for spawning purposes. The season was colder than usual, and the littoral schools of herring were scarce. The diseased fish showed lateral sores in the tail region, and a cavity was hollowed out beneath the "lateral line," and open in places on the surface. Examination proved the presence of a *Neosporidium*, one of the *Myxosporidia*, which spread by means of spores called "sporonts." Each sporont is enveloped in a dense wall which dissolves in the stomach of the fish, after it has been swallowed, and an "amœbula" emerges, which finds its way into the blood, and finally to the various tissues and they thus become infected. The sporont appears to develop into a multinucleate plasmodium, which breaks up into "meronts," by a process of budding, rather than by fission. The sporonts abound where the tissue is in a state of disintegration, the planonts in the blood, liver, etc., and the meronts in the least affected regions. Doubtless the sporont is the means, concludes Dr. Cox, of contamination amongst the herring schools.

VIII.—LIFE OF THE HAKE, A SCALE STUDY (MR. E. HORNE CRAIGIE).

Mr. Horne Craigie, Toronto, reports on the life-history of the hake as determined by the scales. These scales differ from those of the cod, and bear some resemblance to those of the salmon, the centre of the scale being usually a ring with a small anterior break, or else it is a short spiral. It is probable that the lines of periodic growth are annual, but that is undetermined. Most specimens seem to be three years old, and the curves appearing in the "graphs" constructed during the researches, show fairly uniform growth, greatest in the first year and decreasing in later years. Hake appear to spawn mainly in the fourth year and onwards, the spawning period being always one of decrease in the rate of growth.

Females are longer than the males, and are far more numerous; unless the latter associate in separate schools. Of 942 specimens examined only 214 were males.

IX.—GROWTH OF THE HADDOCK—A SCALE STUDY (MISS D. DUFF).

Miss Dorothy Duff, McGill University, summarizes her study on "The Growth of the Haddock," in a report which presents many points of interest. The haddock, as in other allied fish, spawns when it reaches its fourth, or possibly, its fifth year. The rings on the scale, which indicate rapid growth under summer conditions, are wide, but in winter narrower and more compressed. Each band of summer and winter growth represents one year, and by counting the winter rings, the age can be estimated. Growth of the scale is proportional to the growth of the body. Interesting results were obtained when determining the weight of certain organs at different stages of growth. The liver, for example, was 2¼ per cent of the total weight in some instances, but in others, less than 1 per cent, and again in others 4 per cent.

The size of the egg was studied, and it bears no proportion to the size of the ovary, large eggs often occurring in a very small ovary. The eggs in a 4-year-old fish were 1/125 inch in diameter; in 6-year-old fish they were a fifth larger, namely, 1/100 inch. The table at the end of Miss Duff's report is interesting, and shows that a 1-year-old fish may grow to double, or even treble, its length by its second year, and similarly in its third year, but increases only one-seventh or one-tenth in the fourth year; while in the fifth year the increase may be one-eighth or one-fifth, and still less in the sixth and seventh years. One specimen in its eighth year was one-thirteenth longer than in its seventh year, and nearly six times the size it attained in its first year.

X.—GROWTH OF THE COD—A SCALE STUDY (MR. R. P. WODEHOUSE).

Mr. Wodehouse made a similar "Study of the Cod," which is embodied in report No. X. He examined 376 cod from various parts of Passamaquoddy bay, during the period from June 12 to August 12, and while he points out that the scales are a guide to the rate of growth, a retardation in springtime introduces a confusing factor.

It is almost impossible, he says, at times to decide with certainty the age of old cod which have spawned repeatedly. Other factors add to the difficulty, such as the scarcity of food, temporary inability of the fish t osecure ample food for itself, and other conditions which affect the scale-growth. Mr. Wodehouse gives an interesting comparison between some young cod, less than one year old (two batches of them), taken five weeks apart, and showing in that time a growth of slightly less than 1½ inch. By summarizing the tables and striking an average for each year, the author finds that the size of the cod at the following ages may be taken to be: one year, 5·70 inches long; two years, 14·13 inches long; three years old, 19·6 inches; four years old, 25·6 inches; five years old, 32·3 inches; six years old, 35·62 inches; seven years old, 39·09 inches; and eight years old, 45·27 inches.

There is, of course, individual variation. Indeed the author states that "scarcely any two fish have the same life-history."

XI.—DETERRENT EFFECTS OF LIGHT ON MIGRATING EELS (PROF. P. COX).

Professor Cox has completed his third report, contributed to the present series, upon an interesting subject, namely, "The Deterrent Effects of Light on Ascending Eels in Rivers." The theory has been mooted that eels, which are a pest in some rivers, might be excluded by the use of strings of lights suspended across the channels up which they migrate. The experiments were conducted at the end of July, in the tanks of the laboratory at St. Andrews, and later, at the exit of Bocabec lake, New Brunswick. The details are interesting, and show that eels, afraid of the lights at first, hasten back into the darkness but seem to become accustomed after three or four nights' experience, and linger for a longer time in the luminous area. Moving lights were effective for one or two nights, but later they paid little attention to them. Dr. Cox calls attention to the abnormal conditions under which the experiments were conducted.

The usual time for migration of eels was passed, and the fish were transferred from salt water to fresh and *vice versa,* and moreover the fish were penned, not free, in order to facilitate the observations. The conclusion reached is that such lights do not deter migrating eels.

XII.—POSSIBLE AREAS FOR LOBSTER BREEDING IN BRITISH COLUMBIA (DR. MCLEAN FRASER).

Dr. McLean Fraser gives an account of his "Examination of Possible Lobster-Breeding Areas on the east coast of Vancouver Island, B.C.," and in a very full report furnishes details on the nature of the bottom, depth, temperature, density, salinity, etc., of the waters examined from Victoria on the south, to Texada and Lasqueti islands on the north. After referring to the several shipments of lobsters and lobster eggs, by the Dominion Government, from the Atlantic to the Pacific coast, the author expresses the opinion that the temperature in the straits of Georgia is never too high to incommode lobsters, and he found in July, 1914, that the temperatures were as follows:—

63·1° F. at the surface,
56·3° F. at 5 fathoms,
51·0° F. at 20 fathoms,
50·7° F. at 25 fathoms,

while in October the corresponding temperatures were—

52·9° at the surface,
48·65° at 10 fathoms, and
48·49° at 20 fathoms.

The salinity is not very favourable, but is about 80 per cent of that in Passamaquoddy bay, or at Woods Hole, Mass., where lobsters naturally abound.

The suggestion is made that lobsters might be placed in some inclosed inlet where the results could be checked for two to six or eight years, or they could be impounded in a stone or wood inclosure and supplied with food, while under observation, and he specifies six suitable locations.

XIII.—VARIATIONS IN DENSITY AND TEMPERATURE IN BRITISH COLUMBIA WATERS (PROF. CAMERON AND DR. MCLEAN FRASER).

Dr. A. T. Cameron and Dr. Fraser summarize the results of an elaborate investigation into the "Density and Temperature Variations in the Coastal Waters of British Columbia."

For four months the authors made continuous observations at the station, Departure bay, the results of which are lucidly set forth, accompanied by tables, a map and two charts. The distribution of fishes, and marine fauna generally, depends chiefly upon the temperature and salinity of the water, and they point out that the immense outflow of fresh water from the Fraser river affects the straits of Georgia over a great area. With a flood tide the river water is taken in a strong current, in calm weather. to the north, and with the ebb-tide sweeps towards Gabriola pass, Vancouver island, and southward, and, as surface-water, may pass almost unchanged into Departure bay under favourable conditions. High winds and heavy seas with a strong north or south current causes a mingling with the deeper salt water, and the fresh water does not then reach Departure bay. Howe sound on the mainland is influenced by its own fresh-water outflow from Squamish river, not the Fraser river, as is shown by the conditions in Vancouver harbour, and the low values obtaining there. Similarly large bodies of fresh water influence the salinity of Alberni canal, and Barkley sound, on the west side of Vancouver island. These results, say the authors, indicate that in every large inlet along the coast, similar conditions obtain, and much research would be necessary before the relative value of the local streams and of the Fraser river, in different localities, can be stated. An interesting point stated is that bull-kelp flourishes where there is a higher salinity (as the growth, length and weight of the plants, as well as the extent of the beds, increase with the salinity), and the same applies, though in a less degree, to the sea-ivy. The curious ear shell, *Haliotis* (the Abalone) finds most favourable a salinity and depth of water practically identical with those under which the sea-ivy flourishes; that is not below a mean density of 1·019 to 1·020. The authors add that it is desirable in order to find to what depths the sudden fluctuations in Departure bay and vicinity extend, and what are the effects upon plant and animal life (in order to compare these with the regular changes observed near the St. Andrews Station on the Atlantic coast), that investigations should be made over a more extended period than has hitherto been possible.

XIV.—PHYSICAL STUDIES IN SOME NEW BRUNSWICK BAYS (DR. MAVOR AND MESSRS. CRAIGIE AND DETWEILER).

Dr. J. W. Mavor and Messrs. Craigie and Detweiler, in a short paper, summarize their "Investigations of Certain Bays between St. Croix River and St. John, N.B.," with regard to suggested oyster culture.

At the twenty stations where they carried on temperature and density observations, the air temperature ranged from 14·4° C. up to 30·1° C., ranging on the whole between 16° and 17° C. The depths were 1½ to 3 fathoms, to 5, 7, or 10 fathoms. The bottom temperature ranged from 9·4° C. to 15° C., but chiefly ranged about 10°, 11°, or 12° C. The bottom density varied from 1·0085 to 1·02498. The paper concludes with a list of mollusks obtained from the bottom when dredging at seven of the stations.

XV.—HYDROGRAPHIC INVESTIGATIONS, PASSAMAQUODY BAY (MR. HORNE CRAIGIE).

Mr. E. Horne Craigie continued the "Hydrographic Investigations in Passamaquoddy Bay," which previous workers had carried on in former seasons. He selected nineteen stations, so arranged as to give four vertical sections of the area examined: two on the St. Croix river, one of Passamaquoddy bay from Tongue Shoal light to Pendleton island, and one of the western passage.

As the paper itself is a very condensed account of the observations made, it is difficult to give a synopsis, and the twenty-three "graphs" with accompanying explanation require to be consulted, along with the data of sections, and the table of densities, with which the paper concludes.

XVI.—HYDROGRAPHIC SECTION OF BAY OF FUNDY (MR. HORNE CRAIGIE).

Mr. E. Horne Craigie summarizes his "Hydrographic Investigations in the Bay of Fundy in 1914," in a paper illustrated with a chart, five graphs and a table of data, affording information as to the temperatures, movements of the water, densities, etc., in a hydrographic section of the bay, this section extending from East Quoddy Head, N.B., to Digby Gut, N.S.

XVII.—IODINE, ETC., IN CERTAIN BRITISH COLUMBIA KELPS (PROF. A. T. CAMERON).

The concluding paper of the series, by Professor A. T. Cameron, Winnipeg, treats of the "Iodine and Water Contents of Six Species of Kelp on the Pacific Coast," and the tables which are included in the paper are interesting as showing the effect of age and of the period of the year, upon the chemical composition of these algæ. The general results show that the percentage of iodine is almost always less and the water greater in the float of the bull-kelp than in the fronds, or in the stipe. Young plants of that sea-weed contain more iodine than full-grown ones. Yet as the total bulk of the plant increases during the final stages of growth, the full-grown plants yield a greater total of iodine, although the average content be less. An elaborate analysis of eight species of British Columbia kelps is given by Dr. Cameron.

CONCLUSION.

It only remains to add that a further series of valuable reports has been nearly completed by the staff of the Atlantic and Pacific stations, and that a new volume of "Contributions to Canadian Biology" will, it is hoped, be ready for issue within a few months.

The work of the stations is rapidly extending and the interest of scientific investigators in marine researches at the various universities is growing year by year. Increasingly valuable results will, without doubt, follow. The stations so generously supported by the Dominion Government are still able to carry on their important work without salaried officers as the staff conduct their valuable work without compensation. The only exceptions are certain assistants, and the main expenditures therefore are those involved in the operation of the stations, boats, cost of apparatus, chemicals, etc., and the travelling and boarding arrangements which it has been found necessary to provide for the workers at St. Andrews, N.B., and at Departure bay, B.C.

INVESTIGATION INTO THE PACIFIC HALIBUT FISHERIES, BRITISH COLUMBIA.

By Professor Arthur Willey, D.Sc., F.R.S., F.R.S.C.,
McGill University, Montreal.

PART I.—INTRODUCTION.

It is known that the halibut has already passed the zenith of its productivity in the north Atlantic and is now far outclassed in industrial importance by the Pacific race which belongs to the same species. Yet the critical periods of its life and growth, spawning, metamorphosis, and migrations have thus far eluded the efforts of the international commission for the exploitation of the sea, which has accomplished so much in other fields.

The economic history of the halibut fishery on the northwest coast of the American continent may be said to have begun with Indian tradition, and to have culminated in the competitive industry of to-day. The sign of the halibut was used as a crest by the Haidas of the Queen Charlotte islands in the days when that tribe was in the ascendant. Dr. C. F. Newcombe, of Victoria, who is a great authority on Indian antiquities in British Columbia, showed me an illustration of a Haida communal grave house from Cumshewa, which had been installed in the Department of Anthropology of the Field Columbian Museum (see publication 98, report series, vol. ii, No. 4, annual report for 1903-04, Chicago, October, 1904, plate liii, opposite p. 281). The house measures 17 by 20 feet, and in the middle of its facing boards there is a carved post portraying in its entirety the halibut crest, a very rare example. The figure of the halibut may sometimes be recognized in Indian rock-carvings or petroglyphs. An exceptionally interesting animal scene, which ought to be protected from the class of visitors who cut their names or initials on all objects of beauty and rarity, is to be found a little to the south of the town of Nanaimo, carved on a sandstone knoll above a gravel pit off the main road between the Indian reservation and the Chase river. It deserves to be kept as one of the sights of Nanaimo, but will soon be destroyed unless it is cared for by those in authority. Mr. George Waddington, of Nanaimo, kindly gave me a print from a photograph of it which he had taken after chalking over the deeply incised lines. The original, without chalk, does not give the impression of crudeness in its sylvan surroundings, but of typical aboriginal decorative art. The halibut can be seen to the left of the middle of the picture. This petrograph has also been described and illustrated by Mr. Harlan J. Smith and by Dr. C. F. Newcombe.

Accounts of eye-witnesses of the old Indian methods of fishing for halibut have been written by J. J. Lord and G. M. Dawson. Lord, the author of the "Naturalist in Vancouver Island and British Columbia" (two vols., London, 1866), gave a vivid description of his experience in a fishing canoe off the northern end of Vancouver island. He surmised correctly that the species was identical with *Pleuronectes hippoglossus* Linnæ (1758), inhabiting the North Atlantic ocean. This specific determination was subsequently corroborated by Dr. Tarleton H. Bean ("On the occurrence of *Hippoglossus vulgaris* Flem., at Unalaska and St. Michaels, Alaska," Proc. U.S. Nat. Mus., vol. ii, 1879, pp. 63-66). It may be explained that the systematic name of the halibut as given by Jordan and Evermann (Fishes of North America, part iii, 1898, p. 2611) is, in accordance with the rules of priority, *Hippoglossus hippoglossus.* The Linnæan species was promoted to generic rank by Cuvier (1817) and was called *Hippoglossus vulgaris* by Fleming (1828).

In the summary of his anthropological observations on the Haida Indians, published as Appendix A to his report on the Queen Charlotte islands (Report of Progress for 1878, Geological Survey of Canada, Montreal, 1880), Dr. G. M. Dawson referred to the halibut in these words: "The halibut fishery is systematically pursued, and the main villages are so situated as to be within easy reach of the banks along the open coast on which the fish abounds. The halibut is found in great numbers in all suitable localities from cape Flattery northward, but is perhaps nowhere finer, more abundant, and more easily caught than in the vicinity of the Queen Charlotte islands. It may be taken in most of the waters at almost any season, though more numerous on certain banks at times well known to the Indians. About Skidegate, however, it is only caught in large numbers during a few months in the spring and early summer. When the fish are most plentiful the Haidas take them in large quantities, fishing with hook and line from their canoes, which are anchored by stones attached to cedar-bark ropes of sufficient length. They still employ either a wooden hook armed with an iron—formerly bone—barb, or a peculiarly curved iron hook of their own manufacture, in preference to the ordinary fish-hook. The halibut brought to the shore are handed over by the men to the women, who rapidly clean the fish, removing the larger bones, head, fins, and tail, and then cutting it into long flakes. These are next hung on the poles of a wooden framework, where, without salt—by the sun alone, or sometimes aided by a slow fire beneath the erection—they are dried, and eventually packed away in boxes for future use."

The historical aspect of the fishery has been touched upon more recently by Capt. H. B. Joyce, of Seattle, who is known as a pioneer in the halibut fishery of the Pacific coast, and inventor of the net in which the fish are hoisted on deck from the dories. In his "Introductory Notes on the Halibut Fishery" (Bureau of Fisheries, Doc. No. 763, Washington, 1912), Captain Joyce has the following paragraph: "In the early history of the Pacific halibut fishery a large portion of the catch was taken in waters on the south side of Dixon entrance, in Hecate strait, between Queen Charlotte islands and the islands fringing the coast of British Columbia on the east side of the strait. The Indians of this region had fished in these waters from time immemorial, obtaining an ample supply of fish for their needs, and they furnished the first information to the white man of the abundance of halibut on grounds adjacent to their villages. They were instinctively very reluctant to impart the information desired, and with good reason, but constant persuasion on the part of white fishermen and a promise of 50 cents a fish to the Indians for all the latter might catch were inducements too great for the Indians to resist. Fish were furnished by these people which were never paid for; and in a very short time the white fishermen had acquired full knowledge of all the local grounds pointed out by the Indians, and all others which they could locate."

The discovery of fish banks or feeding grounds, where the halibut assembles at times in great schools, is the reward of successful exploration on the part of the master and crew of a fishing vessel. When such a spot has been found, an endeavour is naturally made to keep it quiet rather than to noise it abroad. But no way has yet been hit upon to tie the tongues of fishermen when ashore in convivial humour. All becomes known, new vessels arrive, and the days of full fares and easy trips are soon numbered. The marvel is that the stock of halibut will stand for so long the constant drain that is put upon it. Notwithstanding the enormous fecundity of food-fishes, the necessity of looking ahead and of conserving an adequate stock of breeding fishes in the various species has been engaging the attention of administrators, marine biologists, fishery experts, and others in recent years.

The natural history of the halibut in North American waters, so far as it is known, has been written by Dr. George Brown Goode in "The Fisheries and Fishery Industries of the United States (section I, pp. 189-197, Washington, 1884). He points out that the halibut is a cold-water species, its geographic range approximately

coinciding with that of the codfish. But whereas the spawning of the codfish, as well as that of many other species that discharge pelagic floating eggs, has become well known since modern fishery investigations were inaugurated during the years 1864-66 by Prof. G. O. Sars, operating on behalf of the Norwegian Government in the neighbourhood of the Lofoten islands, that of the halibut has so far baffled all attempts to solve the problem.

With regard to the difficult subject of the migrations of the halibut, which have not yet been investigated by the laborious method of marking, liberating, and recapturing the fishes, it is necessary to distinguish between feeding and spawning migrations. It is certain that they come inshore to feed, but it is not definitely proved that they move into deeper water to spawn. Goode (*op. cit.* p. 195) observes that on the coast of Newfoundland, Anticosti, and Labrador, halibut frequently run inshore in summer after capelin, often swimming to the surface. A. B. Alexander, in his "Preliminary Examination of Halibut Fishing Grounds of the Pacific coast" (Bureau of Fisheries, Document No. 763, Washington, 1912), referring to the locality of Chignik bay, Alaska, says: "It is not uncommon to find halibut in the salmon traps here during the season, and occasionally large individuals are taken in the harbour and lagoon close to the wharves, being attracted from offshore grounds by the offal from the canneries."

The U.S.S. *Albatross*, thoroughly equipped for special service, spent the season from May 25 to August 29, 1911, investigating the commercial possibilities of the halibut grounds off the coast of Alaska, without including the question of propagation in the scope of the inquiry. Even with this restriction, the experience showed that "to cover the fishing banks of Alaska thoroughly and indicate accurately the areas where halibut exist in commercial quantities would require several seasons of active work," but on the other hand, "the phenomenal catches landed in the last few years suggest no stringency of supply on grounds now fished, and this fact will doubtless delay the expansion of the fishery" (A. B. Alexander, *op. cit.*). The *Pacific Fisherman* (Seattle, July 5, 1914, p. 28) contains the following significant market report: "On June 30 [1914] the halibut industry closed another disastrous (from a financial standpoint) month. The independent schooners brought in the largest quantity they ever delivered in Seattle, with the exception of May, 1913, in any one previous month. The company vessels also brought in the largest catch since August, 1913. It is very evident that there can be no permanent improvement in the fishery unless the market for halibut is extended considerably, or the output materially decreased."

Evidence is forthcoming from various sources that the Atlantic halibut is a summer-spawning fish. As for the east coast of America, one of Dr. Goode's informants told him that on the Grand Banks of Newfoundland in August, 1878, he found many with the spawn already run out. This was confirmed by another fishing master who had often seen halibut in July and August, up to the first of September, with ova and milt exuding, at which time very little food is found in their stomachs. But the value of such explicit statements as these is discounted by the absence of preserved material and accessory data.

An early description of the ripe, detached, though not deposited eggs of the Atlantic halibut was given by E. W. L. Holt, whose account is summarized by J. T. Cunningham in "The Natural History of the Marketable Marine Fishes of the British Islands" (London, 1896, see p. 243): "On April 30, 1892, Mr. Holt obtained some ripe ova by pressing the abdomen of a female [halibut] in the market at Grimsby. The eggs were dead, but the transparency and uniform character of the yolk showed that they were ripe. These eggs were 3·07 to 3·81 mm. in diameter. The yolk was like that of the plaice or flounder, colourless, transparent, and undivided, and there was no oil globule. It was evident that the eggs were of the floating kind, although not being alive they did not float. No floating eggs so large as this have

yet been taken in the surface nets at sea.......... In the same year, Professor McIntosh examined two samples of ripe eggs of the halibut * * *. The fertilized eggs have not yet been obtained, nor any of the larval or very young stages" (up to 1892).

In "The Life-histories of the British Marine Food-fishes" by W. C. McIntosh and A. T. Masterman (London, 1897, p. 316), it is stated that: "On the coast of Sweden the spawning season is given as from June to August. On the [Atlantic] shores of North America it lasts till September." On the contrary there are some indications that on the Pacific coast the halibut is a winter-spawning fish. Firstly, there is the conspicuous absence of spawning female halibut from the usual summer catches. If there had been clear evidence of spawning during the experimental hauls made by the *Albatross* in the summer of 1911, notice would have been taken of it. Only in one instance, on July 20, was it mentioned that the eggs "had the appearance of being well developed." I have found the same range of maturation phases during the months of May (west coast of Queen Charlotte islands and Hecate strait) and August (gulf of Alaska), the final stage, ripe for spawning, being always lacking. Of course this might be due in part to the circumstance that the female halibut, like the plaice, does not feed much during the spawning period, and consequently will not readily take the bait. But the possibility of retirement into deeper water (between 150 and 200 fathoms) for the purpose of spawning has to be remembered. It is a curious fact, however, for which there is no accounting at present, that the larger fish are to be found within the 3-mile limit, amongst the rocks in 15 to 30 fathoms, and again at the outer edge of the continental shelf, whilst smaller fish occur in schools on the intervening banks. Here it may be remarked that dory-fishing is best adapted for the inshore zone, line-hauling for the deep sea.

Captain Holmes Newcomb of C.G.S. *Malaspina*, under date September 6, 1914, has furnished me with the following information regarding the question of halibut spawning. He writes: "During the year 1913 I examined from 250 to 550 fish per month; from 28th February to 1st October I found no ripe fish. I took the best samples I could get each month from the best developed fish, averaging from 40 to 50 pounds. These samples were collected from all over the coast; I still have them, and you are welcome to them if of any use. My own opinion is that these fish spawn during the fall and winter months, say from the latter end of October to the first or middle of February."

At Ucluelet on July 16, 1914, I obtained a female halibut weighing 36 pounds, estimated from the scales to be about 10 years old, whose ovaries appeared to be in a spent condition, but after preservation in 10 per cent formalin, they proved to be regenerating, and might well have been spent during the previous winter season. It is the only example of the kind that I observed. How long it takes for a halibut to regenerate after spawning is entirely unknown. The estimation of the age of this specimen is based on a comparison with the figures published by Prof. Playfair McMurrich in his "Notes on the Scale-markings of the Halibut and their bearing on questions connected with the conservation of the fishery" (Trans. R y. Soc., Canada, series 3, vol. vii, sec. iv, Ottawa, 1913).

It is quite probable that the spawn and fry of the halibut are to be sought for in the deeper layers of water; in other words, that they are bathypelagic, and therefore will not be taken in the surface tow-net. The newly hatched halibut larva has never been obtained. The first recorded post-larval stage was described in 1893 by Dr. C. G. J. Petersen ("On the Biology of our Flatfishes," Rep. Danish Biol. Station iv, 1914, pp. 1-146, two pls. See p. 130 pl. ii, f. 20) whose work I have not seen. His figure of the young pelagic stage is reproduced by McIntosh and Masterman (*op. cit.* pl. xii, f. 10). The specimen was 32 mm. long; the migration of the left eye had hardly begun, and the fin-rays were absent from the pectoral and ventral fins.

The only other alleged post-larval stages that had been examined before 1900 were two young pleuronectids taken in the bottom net in the Moray Firth in August, 1896.

There was some doubt as to their identification, inasmuch as another deep-sea flatfish, having the same number of fin-rays in the median fins as the halibut, also occurs in the Moray Firth, this is the pole dab or pole flounder *Pleuronectes* (*Glyptocephalus*) *cynoglossus*. The large mouth and depression above the snout led to the conclusion that they belonged to the halibut species. These two Moray Firth specimens were 12 and 14 mm. long; they were described, with a figure, by Dr. H. M. Kyle [Notes and Memoranda. Halibut (*Hippoglossus vulgaris* Flem.) or Pole-Dab (*Pleuronectes cynoglossus* Linn.). Journ. Mar. Biol. Ass. Plymouth, vi, Dec., 1903, pp. 618-621, pl. ii, f. 2.]. The metamorphosis had hardly begun, the left eye not having commenced its migration; eighteen fin-rays had appeared in the caudal fin, but in the marginal fins the rays could only be detected after being cleared in xylol and mounted in balsam. The spawning seasons of halibut and pole dab overlap in the North Atlantic; but whereas the ripe egg of the halibut measures 3.0 to 4.0 mm. in diameter, that of the pole dab varies between 1.15 and 1.70 mm. The examination of ripe females in British and Icelandic waters has led to the conclusion that the European halibut is a summer-spawning fish (April to August).

Under the provisional assumption that the eggs of the halibut may prove to be bathypelagic, i.e. adrift in deep water, it may be useful to quote the case of *Argentina* as affording the first example of a bathypelagic egg to be made known. *Argentina* is a genus of deep-sea salmonoid fishes belonging to the smelt family, the eggs and fry of which were taken by the Danish steamer *Thor* in deep water in the Atlantic and in the Skager Rak during the years 1903-6. They were described by Dr. Johs. Schmidt (On the larval and post-larval development of the Argentines. Meddelelser fra Kommissionen for Havsundersögelser. Fiskeri Bd. II, No. 4 Copenhagen, 1906). The eggs of *Argentina silus* occur in large quantities floating in water-layers far from the surface over great depth. These pelagic eggs are of large size, 3 to 3.5 mm. in diameter, resembling Muraenoid eggs, from which they differ in lacking a large perivitelline space. The yolk, like that of Clupeoids and Muraenoids, is not homogeneous but is segmented, i.e. it shows a vesicular structure, composed of numerous small cell-like spheres; it contains a large plano-convex oil-globule, with major diameter of 1.0 mm. Eggs were taken in the young fish trawl on June 24, 1906, with 800 metres of wire-rope out, over a total depth of 910 metres. The larvæ hatched out on board and were preserved the same day; their average length was 7.7 mm. The youngest larva taken in the sea with the young-fish trawl measured about 10¼ mm. One of 28 mm. was taken on July 25, 1905, with 500 metres of wire out, over a depth of 512 metres; another of 50 mm. was taken on September 1, 1905, in the young-fish trawl with 75 metres of wire out, over an average depth of 1000 metres.

The striking coincidence in point of size between the pelagic eggs of *Argentina* and the ripe eggs of the halibut seems to give further ground for the presumption that the latter may be found to be bathypelagic. The proving of this detail will spell a notable advance in the knowledge of the life-history of the halibut, and will justify a great deal of trouble.*

PART II.—NARRATIVE.

In pursuance of the inquiry, which lasted from May to September, I made trips round the Queen Charlotte islands, to the west coast of Vancouver island, to Victoria, and to the gulf of Alaska. I was thus able to see something of four methods of halibut fishing, namely, by canoes, by small gasolene launches, by dories from gasolene schooners, and line-hauling by steamers.

Soon after my arrival at the Biological Station, Departure bay, I called on Mr. W. Hamar Greenwood, managing director of the Skeena River Fisheries, Limited, at Vancouver, to whom I had been recommended by Prof. A. B. Macallum. Mr. Greenwood at once gave me permission to accompany one of the company's

* Since the above was written I have received by the courtesy of the author Dr. Johs. Scmidt's paper on the post-larval halibut collected by the Danish steamer *Thor* published in the Danish Fishery Reports, 1904.

schooners operating from the cold storage establishment at Haysport on the Skeena river. I reached Haysport by way of Prince Rupert on May 16, and was met by Mr. Harry Sheere, the manager. The schooner *Roosevelt* had just come in with a catch of about 40,000 pounds of halibut, which were being landed and rapidly decapitated before being weighed. After some delay, due to slight engine trouble, the ship weighed anchor on May 19 at 11.30 a.m., and by sunset at 8.50 p.m. on the same day had gained the middle of Dixon's entrance. Next morning we made the Parry passage between Graham island and North island, and set a course to the SSW. of Frederick island, where we sounded in 33 fathoms on a gravelly bottom, and made the first set. The schooner carried four dories, each dory putting out several skates of gear. A skate consists of seven lines joined together, each line carrying thirty hooks. The catch comprised, besides halibut, red cod (*Sebastodes ruberrimus*), ling cod or blue cod (*Ophiodon elongatus*), and the North Pacific chimæroid or ratfish (*Hydrolagus colliei*).

Red cod and ling cod have nothing to do with true codfish, but they are valuable food-fishes. Nevertheless, in consequence of market exigencies, they have to be rejected by the halibut vessels, and a trial of bright red fish floating dead behind a dory, each with an attendant gull, is a common spectacle. They (i.e., the red cod) have the peculiar property common to other deep-sea fish, though not possessed by the ling cod, halibut, nor true gray cod, of becoming blown out when brought to the surface; the eyes start from their sockets and the stomach is often pushed inside out into the throat. The large bladder-like ovaries of the first red cod which I examined were full of loose eggs in a viscous fluid, like sago. These eggs were transparent, with translucent yolk and a single bright yellow oil drop; they had the usual dimensions of pelagic eggs, not exceeding one mm. in diameter, and I was astonished to observe that each egg contained an embryo coiled round the yolk, with black pigment in its eyes. On stirring up a quantity of the fresh eggs some of the embryos were freed from the membranes, but I saw no twitching of tails. On placing a small cohering mass of them in sea-water, they readily shook apart and sank slowly in the still water, with the oil drops up. I made a rough estimate that each ovary contained 225,000 eggs.

It was known that the Scorpænidæ or rock fishes, to which family *Sebastodes* belongs, are viviparous, but my first acquaintance with the phenomenon surprised me greatly, because in other cases of fishes which incubate their eggs within the body of one of the parents, whether it is in a brood-pouch of the body of either parent, or in the mouth of the male, or in the ovaries of the female, the eggs are relatively few in number, sometimes large in size, and do not exhibit the characteristics of pelagic eggs. Carl H. Eigenmann ("On the viviparous Fishes of the Pacific Coast of North America," Bull. U. S. Fish Commission for 1892, Washington, 1894, pp. 381-478, pls. 92-118) states that in the largest of the Scorpænidæ, *Sebastodes levis*, attaining the length of 2 to 3 feet and weight of 29 pounds, found in deep waters along the coast of California from San Diego to Monterey, and occasionally seen in the markets of Los Angeles, the ripe eggs, about 1 mm. in diameter, would fill about two quarts, each egg developing into a larva before its discharge from the ovary. He adds that there is no month in the year during which the developing eggs of viviparous fishes cannot be procured at San Diego. Over 30 per cent of the bony fishes found at San Diego are viviparous, and all of them belong to one of two families, Embiotocidae and Scorpænidæ. Eigenmann further distinguishes two types of viviparity in fishes: (1) Those in which the yolk furnishes all the intraovarian food, e.g., *Poecilia, Gambusia,* Scorpænidæ; in these the number of young is not reduced; (2) Those in which the greater part of the food is furnished by the ovary, e.g., *Blennius, Zoarces, Anableps,* and Embiotocidæ; in these the number of young is reduced and bears a relation to the size and age of the parent.

The wasteful destruction of red cod and their unborn fry, which is incidental to the halibut fishery, is enormous and reacts upon the latter to this extent, that halibut and ling cod feed upon the red cod, and both are considered superior to the latter on the local markets. But, as already mentioned, the red cod itself is an excellent table fish, particularly after having been split and salted. Jordan and Evermann also state that this species is abundant from San Diego to Puget sound, and is an important food fish. Of five red cod from Hecate strait examined on May 26, one was a spawning female with loose egg-embryos in the ovaries, the others were spent males. Throughout the summer the males exceeded the females in number and size, the exact converse being true of the halibut.

The viviparous perches or Embiotocidæ, to which reference has been made, are shore-frequenting fishes, and their viviparity is quite distinct from that of the rock-fishes or Scorpænidæ. In these we find intraovarian incubation of pelagic eggs, whereas in the perches we have an example of the intraovarian incubation of demersal eggs. This difference is of great interest and bears indirectly upon the problem of the spawning of the halibut which inhabits the same waters as the red cod and possibly produces bathypelagic eggs. On the other hand, it is well known that the ling cod deposits huge clumps of demersal eggs inshore. Dr. C. McLean Fraser informed me that he had found the egg-masses on the rocks near the Biological Station, Nanaimo.

Near midnight on May 21 the anchor was dropped in 18 fathoms in Tassoo harbour, on the west coast of Moresby island, an extensive inlet with a narrow entrance difficult to negotiate on a dark night. On entering it we were assailed with a delicate pine-scented land breeze and greeted by a great chorus of gulls, s me of which were nesting and had just laid their eggs on a rocky islet in the harbour. The depth descends to 70 fathoms, and as it was too rough on the following day to fish outside, a set was made at 20 to 40 fathoms in the calm water of the lagoon. The result was not encouraging, but two of the halibut were of large size, 4 feet and 5 feet long. I went out in one of the dories and hitched a pelagic tow-net on to the buoy-line 3 or 4 fathoms above the anchor in 23 fathoms. Besides the usual complement of Medusæ, Ctenophores, and Siphonophores, one young fish was caught. The hooks, baited as usual with herring which had been frozen, brought up ling cod, red cod, rock cod (*Sebastodes caurinus*), halibut, starfishes, sea-lilies, and sea-anemones. The total number of fish captured was small, and it may be stated, as a general rule, that the inlets and inside channels, despite their great depths, are not suitable for halibut life and propagation. Near the shore at the head of Tassoo harbour there were numerous egg-ribbons of the giant-whelk and a luxuriant growth of eel-grass covered with hydroids which were subsequently identified by Dr. C. M. Fraser as *Obelia longissima*, very common also on the piles of the wharf at the Biological Station.

Shortly after noon on May 22 we left Tassoo harbour and sailed south before the wind, which was blowing harder than ever from the northwest. It was said that the rough weather we experienced was unusual at this time of the year. At five o'clock we arrived off the mouth of another large inlet, with a string of low rocks stretching far across from each point, not named on the chart. It lies south of the San Christoval mountains on Moresby island, opposite to Juan Perez sound. Here we sounded in 120 and 90 fathoms, within a mile of the shore, and put into the inlet for the night. In the evening I rowed round a point of land with the skipper and saw quantities of small crustacea, calanoid copepods, which he recognized at once with his Norwegian experience as "herring feed." They were rising to the surface amongst the kelp, one by one, then swimming round in spirals, clockwise, causing distinct widening ripples at the surface. The same species formed an important constituent of the outside plankton. They may be regarded as forging a link in the chain of metabolism which culminates in the life of the halibut, inasmuch as they subsist upon a vegetable diet (algæ), herrings feed upon them, octopus and rockfish

upon the herring, whilst halibut prey upon octopus, rockfish, herrings, and launces, as well as upon crabs, prawns, and rock-oysters (*Anomia*).

May 23 opened with a gale of wind from the west, and we did not get under weigh until the afternoon. A succession of soundings three-quarters of a mile offshore gave deep water, with bottom shelving abruptly to 200 fathoms (found no bottom at 170 fathoms). The limit of the continental shelf lies approximately at the line of 150 fathoms; this line may be 30 or 40 miles offshore, or it may be within territorial waters. At the position where we sounded, the available stretch was too short to venture a set. A flock of "whale birds" or shearwaters came in sight and disappeared one by one under the water, soon afterwards reappearing swimming on the surface. Immense flocks of these birds are sometimes seen, and their presence is welcomed as an indication of abundant food and life in the sea. The wind was succeeded by rain as we entered the Houston Stewart channel and came to anchor in Rose harbour at 8.30.

Next morning, the weather having moderated, we got under weigh at dawn and made a set outside the channel in 50 fathoms, leaving the lines out for three hours, getting about equal numbers of halibut and red cod. In the afternoon another set was made in 100 fathoms, resulting in the capture of the largest halibut of the trip, a female 74 inches long, estimated to weigh 100 pounds. The ovaries were 17 inches long, and together weighed 4½ pounds; they contained under-sized eggs, apparently requiring several more months to reach maturity. Another halibut had the remains of a red cod in its stomach. The hooks also brought up a magnificent scarlet fan-coral (Gorgonid) 4 feet high, with thick anastomosing branches and horny axis 1½ inches in diameter near the base. Attached to the basal portion of the stem was another encrusting colony of Alcyonarian polyps belonging to the genus *Clavularia,* with whitish polyp stems and roseate polyp-heads. I submitted samples of both species to Prof. S. J. Hickson, of Victoria University, Manchester, England, who favoured me with the following information about them: "The large Gorgonid is probably *Primnoa pacifica* which was described by Kinoshita in 1907 (J. Coll. Sci. Japan, xxiii) from the Japanese coasts. He describes this species when alive as being rosy red in colour. To be perfectly certain that this is a correct identification, I should have to examine a large dried specimen so as to compare them as regards the mode of branching, but I have little doubt that it is this species. The *Clavularia* appears to be *Clavularia pacifica* of Kükenthal (Zool. Jahrb. Syst. xxxv, 1913, p. 237), but it differs from this species as regards the spicules. The spicules of your specimen are similar, but much more numerous. They are very much the same shape, but are not so large, and inclined to become club shaped. I have noticed also that there are not so many arranged transversely in the region of the calyx."

This closed the exploration of the west coast of the Queen Charlotte islands. In the evening we were crossing the southern end of Hecate strait in the direction east half south. During the night a succession of heavy squalls with rain struck the ship from the south, causing the skipper to heave to. About 10 a.m. on the following day we encountered enormous numbers of "whale birds" flying to windward, accompanied by smaller flocks of little black divers with white bellies, which commonly sport like herrings at the surface, called "bull birds" by the sailors, and Mother Carey's chickens (stormy petrels). The petrels fluttered about floating matter at the surface of the sea like swallow-tailed butterflies on moist ground. In rough weather they alight on the surface momentarily without closing their wings; they may dive for an instant below the surface, rising again at the same spot and continuing their flight. In the middle of the strait fur seals were seen bobbing vertically in the water, then diving with a curvet like a porpoise; hair seals were seen from time to time during the voyage close to the shore in various inlets; and sea-lions off the western entrance to Houston Stewart channel. After many soundings and changings of the course we anchored in mid-channel in 57 fathoms. The *Roosevelt* rolled terribly, rendering the

recumbent attitude in an athwartships bunk very unstable. In the evening, however, the sea began to go down gradually, and after supper a Seattle schooner hove in sight and anchored close by.

On May 26, 27, and 28, we were fishing over the Goose Islands halibut grounds, which cover an area some 30 miles square to the west of Goose islands in the southern part of Hecate strait. This is an extensive gravel patch at a depth varying from about 28 to 50 fathoms. Living half buried in the bottom are numerous orange red sea-pens (Pennatulids) called "Stickfish," amongst other nautical designations. Their length averages 4 inches, and their presence is hailed as a sign of good halibut feeding ground. At the outside edge of the bank the depth descends rapidly to 90 fathoms, and here the fishing was not so good, only a few halibut, black cod (*Anoplopoma fimbria*) and a species of flounder being taken. Several other vessels, including a steamer, were now working the same ground. A set which we made in 45 to 50 fathoms yielded a total catch of 225 halibut, representing an aggregate weight of about 2000 pounds, none being larger than medium. It is characteristic of the summer schools of halibut that they consist mainly of comparatively small and immature fish. On the 28th we suffered a repetition of heavy rain and southeast squalls, making dory-fishing precarious, and we wound up the day by finding an anchorage in St. John harbour, Bardswell group, to the south of Millbank sound. The Vancouver steamer which has been referred to had already reached this haven of refuge.

May 30 was the first really fine day of our voyage. Up till now the skipper said the weather had been as bad as he had ever known it in winter. At daybreak we steered west by south half west across Millbank sound towards the Outer islands below Price island, and made a set across the wind from 50 to 60 fathoms on the Price Island ground about 8 miles WSW. of Price island. Amongst the halibut there were two large fish. I made an oblique haul of the tow-net over this ground, finding many calanoid copepods, but phytoplankton (*Algæ*) predominated, and there were no fish eggs. In the afternoon we steered to the northwest across Laredo sound towards entrance island at the south end of Aristazable island. Here a set was made in 30 fathoms about three-quarters of a mile from the shore, amongst rocks. Some large halibut were taken, a male ling cod, which milted freely on deck, many red cod, and a few variegated black and yellow rock fish (*Sebastodes nebulosus*). The halibut averaged a good deal larger than those from the gravel patch of the Goose Islands ground.

The Horseshoe bank was broached on May the 31st, a set being made in 40 to 50 fathoms on a sandy bottom. The position is midway between Lyell island (Queen Charlotte group) and Estevan island below Banks island, both points of land being visible in the distance on a clear day. A mark buoy was put out near the southern end of the set and the four dories lowered their lines in parallel strings about half a mile apart, in such a way that the first line of hooks lay towards the southeast, the last line towards the northwest. The catches made by the individual dories, commencing with the most southerly, were the following: No. 1 caught 107 halibut; No. 2, 117; No. 3, 57; No. 4, 18. This is instructive in exhibiting the schooling habits of the halibut, fairly large numbers being taken at one end of the set, few at the other end. Some of the halibut had been feeding on sand launces (*Ammodytes personatus*). The hooks also brought up a so-called bastard halibut (*Atheresthes stomias*), sometimes wrongly called "turbot," four true grey codfish, and the empty egg-capsule of a large skate. Altogether, three sets were made on this day, the total catch for the day amounting to 580 halibut, about 7,000 pounds. After supper the men were busy dressing the fish and packing them in the ice hold. We anchored in 35 fathoms at a good distance from the mark buoy, and on the following day resumed the fishing on the same ground. The catch included a medium-sized male halibut, whose large-lobed testes contained ripe fluid milt. The maturity of the male is no guide to the incidence of spawning. It was the only case of the kind which came under my obser-

vation as regards the halibut, but is comparable to the case of the male ling cod noted on May 30. With reference to the latter, I applied to Dr. C. McLean Fraser at the Biological Station, Departure bay, for information concerning the date at which he had found the spawn. Dr. Fraser has a paper in the press dealing with the development of the ling cod, shortly to appear in the Transactions of the Royal Canadian Institute, but he kindly writes in advance as follows: "The earliest date I have recorded for attached spawn of *Ophiodon* was January 27. I do not think these eggs could have been laid more than a couple of days, as I had been around the spot several times not very long previous. Shortly after this the bunches of eggs became common, and I should think that the most of them that I have seen were laid in the early days of February, say before the 15th. As they take so long to hatch out, and since there is so little change in external appearance except when the eyes show through, it is impossible with a casual glance at least to tell the old from the new, and hence it is of little value to record any but the early ones. Those that were first seen hatched out on March 25, so that the period of hatching must be about two months."

The trip of the *Roosevelt* came to an end on June 2, whereupon I returned to Nanaimo. There seemed to be a good chance to procure samples of halibut from the west coast of Vancouver island and have them delivered at the laboratory, where I could have examined them with a great deal of convenience. Unfortunately, the negotiations to this end fell through owing to the difficulty of transporting whole fish from the deep-sea fisheries to Vancouver and again from Vancouver to Nanaimo. Accordingly I called on Mr. E. G. Taylor, Inspector of Fisheries at Nanaimo, with the intention of paying a visit to the fishing centre of Ucluelet at the mouth of the Alberni canal. Mr. Taylor advised me to go first to Clayoquot and to take in Ucluelet on the way back. I left Port Alberni on July 9 on board the *Princess Maquinna,* where I met Dr. C. F. Newcombe, of Victoria, whose knowledge of the west coast of British Columbia, its peoples and products, is unrivalled. At Clayoquot I lost no time in getting into touch with Mr. John Grice, the fishery overseer of that district, who did all in his power to assist me.

At my request, Mr. Grice took me to the Indian village of Opatsat on Mears island, where only two families remained, the rest having gone for the season to the Kennedy River salmon cannery, and elsewhere. At Opatsat I saw strips of halibut drying on lines in the open air, as described by Dr. G. M. Dawson, and also in the dwelling-house. Here an agreement was made to secure the services of an expert Indian fisherman, known to the settlers as "Little George." The next morning Mr. Grice conveyed me in the *Heron* as far as the outer islands of the sound, where the Indian was already fishing for bait. A thick fog settled down and continued at intervals all day. I dropped quickly into the canoe and the launch returned to Tofino. The canoe was a large one dug out of a cedar log, light enough for a strong man to manage with a single paddle at the stern or a pair of oars near the bow, and buoyant enough to sail 30 miles out to sea in order to spear fur-seal in the spring. We went close to the lighthouse rocks, where the siren was booming, riding easily in the midst of the white foam washing back from the breakers, and caught a fish which he called "quikima," a "rock salmon" (*Sebastodes* sp.), with a hook baited with a small tassel of cord and white spindle-shaped stick in front of the hook. Using pieces of the fish for bait we tried for halibut at several positions up to the 3-mile limit without success there being too much fog to get correct bearings. The following day (July 12) opened with fog, which cleared away later. The Indian came for me shortly after 5 a.m., since, according to his notion, halibut chiefly feed in the morning. We fished with four hooks baited in the Indian fashion, in about 25 fathoms, 3 miles off the lighthouse island, catching one halibut and one dogfish (*Squalus suckleyi*). The halibut was an immature male of small size, 28¼ inches in total length, weighing 9¼ pounds, age estimated at 7 years, the stomach full of crabs.

Through the kind mediation of Mr. Grice, I now made arrangements with Little George and another Indian named Peter to take me by canoe to Ucluelet, fishing on

the way and reaching Ucluelet in time to spend a couple of nights there and to return by the mail launch *Tofino* to Port Alberni. On July 14, Little George took his net down the inlet to catch viviparous perches (Embiotocidæ) for bait, as it was too foggy to look for octopus. He gave me to understand that these perches are nearly as attractive as octopus for halibut. Large octopus or devilfish are worth two dollars apiece, or 25 cents for each arm. If salted they can be kept for as much as six months; and a single baiting may account for a dozen halibut, this being their favourite, as well as their toughest natural food. Next to octopus the best bait for native halibut hooks is salmon. In the afternoon they came for me in a fine new sailing canoe, bringing a long line with seventy hooks. We took provisions on board and left Clayoquot at 4 p.m., arriving at an Indian reservation on Long Beach, distant 9 miles, about 8 p.m.

After landing at Long Beach they cut the fish into shacks, discarding heads and offal, and baited the hooks ready for the morning, littering the ground with the young. There were two species, a smaller and a larger. I examined a specimen of each: the one contained eight young, the other twenty-two, all ready for birth. We spent the night in the Indian house, and the men went off at 4 a.m. to try for halibut. I was expecting that they would go out to a halibut bank well known to them, called T'ach-ken, which lies 4 miles to the southwest from the northern point of Long Beach bay, but they returned at 6.35 a.m., reporting too much wind outside, and bringing two dogfish and two skates (*Raja binoculata*). The continual strong head wind obliged us to abandon the exploration of T'ach-ken, and we left Long Beach at 10.30 a.m. At noon we made a set in 20 fathoms at a position 1 mile from the Indian house. After fifty minutes the line was hauled in and the bait was found to be untouched. They said the water was too dirty; moreover the southwest wind was increasing and the sea was getting heavy and very choppy. It was a fair wind for Ucluelet, and open water all the way; the men were masters of their craft, and we reached Ucluelet without mishap at five o'clock.

At the entrance to the Ucluelet arm of Barkley sound, there was a floating scow which served as a fish-market, where halibut was received in order to be transported to the Uchucklesit cold storage on the Alberni canal. There is a brisk fishery conducted by owners of small gasolene launches and Indian canoes. I went alongside a fishing launch which had just come in with a load of halibut on July 16 and purchased the largest one there. The total length was 44 inches; weight, 36 pounds; the scales with nine narrow zones indicating an age of 10 years; stomach containing crab remains. The ovaries presented a congested and spent appearance, but after preservation they were found to be in a state of regeneration, with multitudes of growing eggs. Probably spawning had taken place in the winter or early spring. As usual, the anterior half of the body was infested with ectoparasitic flukes; these are commonly found on the white side of the body, but in this case they occurred on both sides. They belong to the same species as those infesting the skin of the Atlantic halibut, viz., *Epibdella hippoglossi.* The halibut banks in this district lie 8 to 12 miles outside the Ucluelet arm. On this occasion it was perfectly clear weather in the harbour, but foggy outside. I was informed (and I know it is true for July) that fogs prevail in July and August, gales in December and January, the two last being critical months in the life-history of the halibut. Thus the investigation in these waters is beset with all kinds of difficulties. Close to the floating scow mentioned above, stands the life-boat station on a point of land, and adjoining this there is a wooded islet with a ruined house on it which, if repaired, would answer well as a temporary biological station.

On July 23 I called on Dr. Charles Francis Newcombe at Victoria who showed me the utmost kindness, and put such of his vast stores of learning as I was able to assimilate at my disposal. In his company I inspected the collection of Indian halibut hooks and floats at the Provincial Museum. Mr. Ashdown Green, a veteran surveyor and pioneer of British Columbia, told us that he had seen ornamental or ceremonial

halibut hooks made of abalone shell (*Haliotis*) in earlier days. The common hooks were made of bone, and later of iron. The former existence of ceremonial hooks and halibut crests is a fact of historical interest in connection with the Pacific halibut fishery.

On my return to Departure bay I wrote to Inspector J. T. Williams of the Dominion Fishery Service at Prince Rupert, to whom I had been recommended by Chief Inspector Cunningham, to request his good offices in securing permission for me to accompany one of the steamers belonging to the Canadian Cold Storage Company to the gulf of Alaska. This was arranged without difficulty, thanks to the willing courtesy of Messrs. Johnson and Nicholl, manager and controller respectively of the company's plant at Seal Cove, Prince Rupert. It was desirable to put off the trip until a late moment in order that the examination of the halibut grounds might be made to cover as long a period as was possible during the season. Accordingly I set out once more for Prince Rupert on August 6, and booked a passage by the ss. Prince George from Vancouver. This was the day of the declaration of war, one effect of which was that the sailing of the vessel was cancelled, so that I had to transfer to the *Princess Alice,* which duly sailed north on August 8, reaching Prince Rupert two days later. It was the first dry day after forty days of almost continuous rain. In the afternoon I walked over to Seal Cove, after having conferred with Inspector Williams, and met the above-named gentlemen who informed me that the steamer *G. E. Foster,* which I was to join, had not yet been sighted. Eventually she came in about 6 p.m. on August 12. I had to sign on board as "cook's assistant," and the voyage commenced shortly before 1 a.m. on August 15.

After calling at Ketchikan, we continued north along the inside passage through Tongass narrows into Clarence strait which separates Prince of Wales island from the mainland. At 6.50 a.m. on August 16 we rounded cape Ommaney at the southern extremity of Baranof island, on which Sitka stands, and set a straight course across the gulf of Alaska to the south end of Kodiak island, distant 650 miles. During most of the voyage across the gulf and back the ship was accompanied by a large brown bird called a "goony," behaving something after the style of a tropical "booby." Sometimes several of them alighted on the surface close to the ship. Numerous other birds were seen far out of sight of land, shearwaters, puffins, and petrels, but the soundings gave no bottom until the evening of August 19, when land was sighted and the captain anchored at 10 p.m. in 54 fathoms on a bottom of greenish sand and gravel, about 20 miles southeast of the Trinity islands to the southward of Kodiak island. The Trinity islands ground is a continuation, south and west, of the great Albatross bank, which flanks the southeast side of Kodiak island, and juts out to the northeast into the Portlock bank. All this forms part of the submerged Alaskan plateau or continental shelf, the edge of which is approximately marked by the 100-fathom line of soundings which is sometimes 50 miles from the nearest land. At certain spots on the plateau there is a great deal of mud, and it is notorious that the halibut taken at such places are soft and gray and of inferior quality; these are called low-grade halibut, and are often rejected. The cause and nature of the change in the consistency of the flesh have not been investigated.

The fishing on the first day did not come up to expectations, the amount taken being estimated at 5,000 pounds. At least as great a quantity of true grey cod was thrown away. The halibut taken on the Albatross and Portlock banks belonged to the same class and quality of fish as those from Hecate strait, presenting the same range in size, the same colour and consistency, and the same degree of immaturity. A large one, measuring 46 inches in total length, weighed 45½ pounds; the ovaries weighed 2 pounds, and the eggs, as in all other cases examined, were fast in their follicles.

For the rest of the trip the weather was almost continually unfavourable for fishing, with strong southeast wind, heavy sea, and fog. The hooks brought up from time to time Actinians and Ascidians with the stones to which they were attached,

as well as hydroids and fan-corals. On one occasion the captain picked up from the deck of the ship what he took to be a stone and was about to throw it overboard when his hand was nipped by a claw. The apparent stone was a stone crab (*Rhinolithodes wosnessenskii*), taken on the halibut line from a depth of 50 fathoms on the Albatross bank abreast of Trinity islands. A sample of hydroids from the same grounds collected on August 20 included fifteen species identified by Dr. C. McLean Fraser, of which seven were recorded for the first time from Alaskan waters, and one had not been described before. The common fan-coral of these waters has a delicate pink colour in life, bleaching quickly to white; the branches have a beaded or moniliform structure, owing to the polyps being arranged in whorls. Prof. S. J. Hickson, to whom a specimen was submitted, states that it is a primnoid fan-coral, probably belonging to the genus *Caligorgia*. All these indications have their value in defining the nature of the ground and in showing how much remains to be ascertained concerning the organisms which inhabit the bottom frequented by halibut in the North Pacific.

At the northern end of the Portlock bank there is a narrow depression or gut where the depth descends below 100 fathoms. At midnight on August 22 we dropped anchor in 140 fathoms in the Portlock gut, and on the following day we set out the gear in 110 fathoms shoaling to 95 fathoms. A great school of Finback whales was spouting and curvetting in the offing. The bottom here consists of sand and fine mud, numerous small starfishes (*Ctenodiscus crispatus*) having their stomachs gorged with the mud. Basket stars, heart urchins, and apodous holothurians were also abundant, the last being especially characteristic of this position. They are probably the species *Chirodota discolor* Eschscholtz, with twelve peltato-digitate tentacles, about nine digits on each tentacle, and very numerous calcareous supporting rods in the tentacles; but I did not find any wheel-shaped calcareous bodies in the skin [compare H. L. Clark: The Apodous Holothurians. Smithsonian Contributions to Knowledge, vol. xxxv, Washington, 1907, p. 26 and p. 120]. They are fragile, soft, worm-like creatures, brownish and pinkish, very prone to self-mutilation or autotomy. The halibut taken here often had one or two large leeches on the white side; these showed nineteen transverse brown bands on the dorsal side, feebly indicated below, the bands are darker parts of a pigmented network, and are generally interrupted at the sides, which are colourless. One halibut contained an entire codfish in its stomach, and yet took the herring bait.

There was no fishing on August the 24th as the tide was too strong, with a heavy sea. A buoy and keg were put out to test the tide, and within an hour the keg had been drawn under water. On August 25 a set was made in 95 fathoms at a spot about 40 miles south of cape Cleare, which is 180 miles east of cape St. Elias. The tide proved to be setting strong from NW. to SE., and the gear was laid across the tide, which carried it over the edge of the continental shelf into 150 fathoms. A great many black cod were caught, one grey cod, several red cod, and a large halibut with total length of 55½ inches, weighing 85 pounds; the ovaries weighed 3½ pounds; numerous nematode worms were encysted at the surface of the liver and intestine and in the ovarian capsule.

August 26 was the stormiest day of the voyage. We were now heading for Cross sound, and making very slow progress against wind and sea, the glass falling steadily all the time. About 7 a.m. on August 28, land loomed ahead enveloped in mist, which shrouded the mountains and obscured all marks. At noon we entered Cross sound, and our worst troubles were over. We anchored that night at Tenakee inlet off Chatham strait, in 70 fathoms, and rode through another very heavy squall. On August 29, whilst abreast of cape Decision we passed a large blue shark with its dorsal fin above the water after the manner of a Finback whale; and on the following day, after being stopped by the patrol cruiser H.M.C.S. *Rainbow*, reached Prince Rupert. I immediately transferred to the *Princess Royal*, which had already cast off her moorings, and in due time arrived at Nanaimo.

PART III.

Conclusion.—Halibut is classified for the market according to size: chicken halibut, ranging from 20 to 29 inches in total length from the end of the snout to the middle of the edge of the tail-fin; medium halibut, 30 to 39 inches; large halibut, from 40 inches upwards. They never approach maturity as "chickens." Accepting the principle of the scale-markings as a basis for estimating the age, it is a singular and useful fact, which follows from Professor McMurrich's observations and from my own measurements, that at least up to the twelfth or thirteenth year the age of the halibut is, with sufficient approximation, equal numerically to one-tenth of the total length measured in centimetres. Thus a fish of 28 inches (= 70 centimetres) is 7 years old; another of 44 inches (= 110 centimetres) is in its eleventh year. The proportions vary (perhaps by sex) and change as the fish grows. This may be illustrated by comparing the maximum expanse of the powerful tail-fin, measured across from tip to tip, with the width of the body measured on the white side between the bases of the median fins (see table below). It may be of interest to remark that the great horizontal expanse of the tail-fin, considered in conjunction with the exceptional swimming powers possessed by the halibut, is paralleled by the horizontal tail-flukes of the Cetacea and by the flattened tail of the beaver.

TABLE of Correlated Measurements.

No.	Length.	Width.	Expanse of tail fin.	Weight.	Sex.
	inches.	inches.	inches.	lb.	
1	$21\frac{5}{8}$	$6\frac{1}{2}$	$6\frac{5}{8}$	$3\frac{1}{2}$	Probably female.
2	$28\frac{1}{4}$	$9\frac{1}{2}$	$7\frac{3}{4}$	$9\frac{1}{4}$	Male.
3	33	10	$10\frac{1}{8}$	....	Probably female.
4	44	14	12	36	Female.
5	$48\frac{1}{4}$	$15\frac{1}{2}$	$12\frac{7}{8}$	....	Probably female.

The halibut is a hardy fish, coming to the surface without showing any reaction to the change of pressure, and continuing to live for some time on deck after being roughly shaken off the hook. Once I saw one disengage itself from the hook as it reached the surface and return rapidly towards the bottom. It would therefore not be difficult to select undamaged individuals and keep them alive in the well of a ship for experimental purposes. The provision of a suitable well such as for many years the Grimsby halibut boats in England have had, should form part of the equipment of any vessel which may be detailed for the scientific branch of the fishery service in the future. It would be a great advantage to observe halibut under experimental conditions for a lengthened period so as to be able to test its viability, rate of growth, and discharge of spawn.

According to Dr. T. W. Wemyss Fulton (on the Rate of Growth of Fishes, 24th Ann. Rep. Scottish Fishery Board, part iii, pp. 179-274, Glasgow, 1906) the approximate size of the female halibut at maturity is 48 inches, that of the male 30 inches. As explained above, a length of 48 inches indicates an age of about twelve years. Professor McMurrich came to the conclusion that the spawning period begins in the eighth year and lasts without any decided interruption throughout the succeeding four or five years. Fulton says that among flatfishes it is a common rule that the male comes to maturity a year earlier than the female; thus the male plaice matures at 4 years old, the female at 5. The female turbot attains maturity at the size of 17 to 18 inches, and at the age of 7 years. The turbot and plaice attain the same approxi-

mate maximum size, namely, 32 inches; the turbot (over 20 pounds) is more heavily built than the plaice (up to 10 pounds. The halibut attains the length of 84 inches. The interpretation of spawning marks on the scales is a very intricate problem and, as McMurrich justly odserves, the course of events as deduced from the scale-markings must be regarded rather in the light of a tentative suggestion. It is, however, quite possible that the Atlantic and Pacific halibut may mature at different ages. According to J. T. Cunningham, there is a difference of about 4 inches between the sizes of plaice at maturity in the English channel and in the North sea; moreover all individuals do not become mature at the same size in a given locality.

The halibut industry of the Pacific coast presents the usual complications attendant upon deep-sea fisheries elsewhere. The distribution of the halibut does not conform to international boundaries, but is continuous from the gulf of Alaska to cape Flattery. There is no evidence at present that the halibut performs extensive north-and-south migrations, though there are abundant indications that it ascends in schools, and also as individuals, into comparatively shallow water (about 15 fathoms) near the shoreline, which is generally steep-to on the west coast, and descends into deep water (about 150 fathoms) near or over the edge of the continental shelf. As mentioned in part I, there are reasons for presuming in a general way that the halibut approaches the shore in pursuit of its food, and descends to the depths for the purpose of spawning. Not only do the known habits of the halibut point in this direction, but the inference receives some support from the analogy of the spawning migrations of the plaice off the coast of Great Britain. It has been established by the recovery of marked fishes at the Plymouth laboratory "that a large proportion of the plaice to be found in Start bay make a periodical migration to the offshore grounds on the approach of winter. Dr. Kyle observed that the majority of the plaice recovered offshore from January to April in this experiment were either spawning or spent. After this spawning migration has taken place the smaller fishes tend to return again to the bays. The largest fishes may either return to the bays, or may pass to the south and west of Start point." [Walter Garstang: Report on Trawling and other Investigations carried out in the Bays on the South East Coast of Devon during 1901 and 1902. Jour. Mar. Biol. Ass. U.K. (n.s.) VI. December, 1903, Plymouth.]

It is obvious that the investigation of the natural history of the halibut in its relation to the maintenance of the stock at its full strength cannot be confined within territorial limits, and it is almost equally clear that if any restrictive measures were to be proposed, they would have to be based upon international agreement. The stock of the halibut is the object of persistent attack, to the exclusion of other fishes captured incidentally, whose food value to the human race is not inferior, in order to supply the demands of an artificial market. Under these conditions we have to consider whether the stock of halibut will continue to stand the strain that is imposed upon it. Practical fishermen are sometimes apt to be pessimistic in this regard, although the aggregate catches do not yet show any sign of diminution. Up to a certain point the thinning out of the banks by the capture of surplus fishes must be beneficial to the numbers and quality of those that remain. But this optimum standard of fishing intensity is vague and cannot be defined otherwise than arbitrarily. Recommendations to curtail the fishery are easily made but they would be entirely ineffective unless there happened to be a clear case for the immediate enforcement of rigid restrictions. The fact is that there is no such pressing call for drastic action, and therefore this aspect of the question need not be discussed here. What we are asked to do is to devise measures for the expansion, not for the limitation of the industry.

In order to throw some light upon the periodical movements of halibut, in the absence of marking experiments or supplementary to such experiments if they could be carried out, there is need for the accumulation of numerous properly authenticated

records of catches with memoranda of date, locality, and depth. Records sufficiently accurate are in fact kept in the ship's log book, at least in some cases, and it should be possible to arrange with some of the great companies for the tabulation of these data so as to make them available for future reference. Statistics of the aggregate catches are easily obtained, but no detailed list of fishing stations accompanies them. Perhaps the organization of a system of marine fishery statistics, including list of stations, depths, methods of fishing, kinds of fish caught, dates, and observations on the weather and currents, would be the first step towards a reasonable grasp of the state of the fishery from year to year. The difficulty here would be to ensure accurate statements of depth and locality because the owners of vessels operating in neutral waters would not feel disposed to give exact and gratuitous information merely to encourage the others. Moreover, the fixing of positions by the charts as they stand could, in many cases, only be a rough approximation. Nevertheless the alleged depletion of once productive banks requires some such scrutiny as that here suggested before it can be explained.

The artificial propagation of halibut in spawning ponds is a colossal experiment which might be tried in order to give an earnest of the endeavour on the part of the scientific departments to do something of direct economic value for the fishery. It is certain that nothing can be accomplished in this way without considerable expenditure, and nobody could guarantee positive and successful results. The cultivation of the plaice is a straightforward procedure offering no insuperable difficulties. It is only necessary to collect mature fish of both sexes and keep them in captivity under usual precautions of water-circulation, temperature, and food-supply, until spawning occurs. The turbot offered greater difficulties which have been overcome in the experimental stage. In February, 1907, Dr. R. Anthony, Assistant Director of the Marine Laboratory in St. Vaast-la-Hougue, procured ten adult turbots which he placed in three large hatching basins, the largest having a capacity of 300 cubic metres. At the end of a few weeks the captive turbot began to take food. They were fed once a week with large pieces of plaice at the rate of half a fish the size of the hand to each turbot, a designedly moderate allowance. To keep the basins free from putrefying food-substances, they put in, as scavengers, a conger eel and a dogfish long since accustomed to captivity. The turbots began to spawn in July. The brood stock should be captured six months before breeding. If taken only a few weeks before spawning time they would be likely to exhibit the phenomenon of ovular retention to which they would succumb. Five consecutive spawnings were observed on July 18, 21, 28, 29, and August 3. There were thousands of eggs in each lot, all normal and fertilized. Only limited numbers were gathered by plankton nets and transferred to the incubating apparatus, an essential feature of which is continual agitation of the water by a suitable mechanism to keep the eggs free from sediment and thus to prevent asphyxiation. Hatching occurred in six to eight days after spawning, and artificial feeding by carefully sifted plankton administered daily was commenced two to three days after hatching. The yolk sac disappeared fourteen to fifteen days after hatching, and the critical stage was passed about the eighteenth to twentieth day. [R. Anthony: La piscifacture du turbot au lab. mar. du Muséum (Saint-Vaast-la-Hougue) Bull. Mus. Paris t. XIII, pp. 557-559, 1908. Translated and presented before the Fourth International Fishery Congress held at Washington, U.S.A. September 22nd to 26th, 1908: Bull. Bur. Fish. XXVIII. Doc. No. 686, Washington 1910.]

Pending the inauguration of this great experiment, efforts need not be relaxed to continue the work already begun. To do this effectively a vessel, properly equipped for special service, should be chartered or commissioned to undertake explorations, not merely to locate fresh halibut grounds on the west coast, but to record observations on the state of maturity of halibut throughout the year, especially during late autumn, winter, and early spring, and to make determined efforts to discover the pelagic eggs by means of the deep sea tow-net. It is difficult to see what more or what else can be done to promote the interests of the fishery, except the compilation of statistical tables.

In the report by Dr. B. W. Evermann on the Alaska Fisheries and Fur Industries in 1913 (Bureau of Fisheries, Doc. No. 797, Washington, 1914) it is pointed out that "the commercial value of the halibut fishery of the Pacific now greatly exceeds that of the Atlantic, and in Alaska, as in British Columbia, it is second in importance only to the salmon fishery." Dr. Evermann adds the following statement: "It is believed to be a safe estimate that for every halibut caught at least one other fish of more or less value as food is taken from the hooks. With those rare exceptions when black cod are retained, all these fish are thrown back into the sea, either dead or soon to perish. Except in so far as they may become food for other species, they may be regarded as a total economic loss. The most abundant are the red rockfishes and the black cod, with the former [" red cod "] predominating in number when all grounds are considered. True cod are found in largest numbers where the depletion of halibut is most pronounced; and deep-sea soles, flounders, and skates are most numerous on a muddy bottom. It is certain that the total quantity of these fishes at present wasted is enormous in the aggregate; in weight it is probably at least one-half that of the halibut itself. That such a situation should not long be allowed to continue is obvious."

The state of things depicted in the above quotation has been referred to incidentally in the pages of this report. The remedy, if one can be found, would seem to lie in the direct encouragement of the companies by Government to take measures to divert the hitherto rejected food-fishes into more profitable channels.

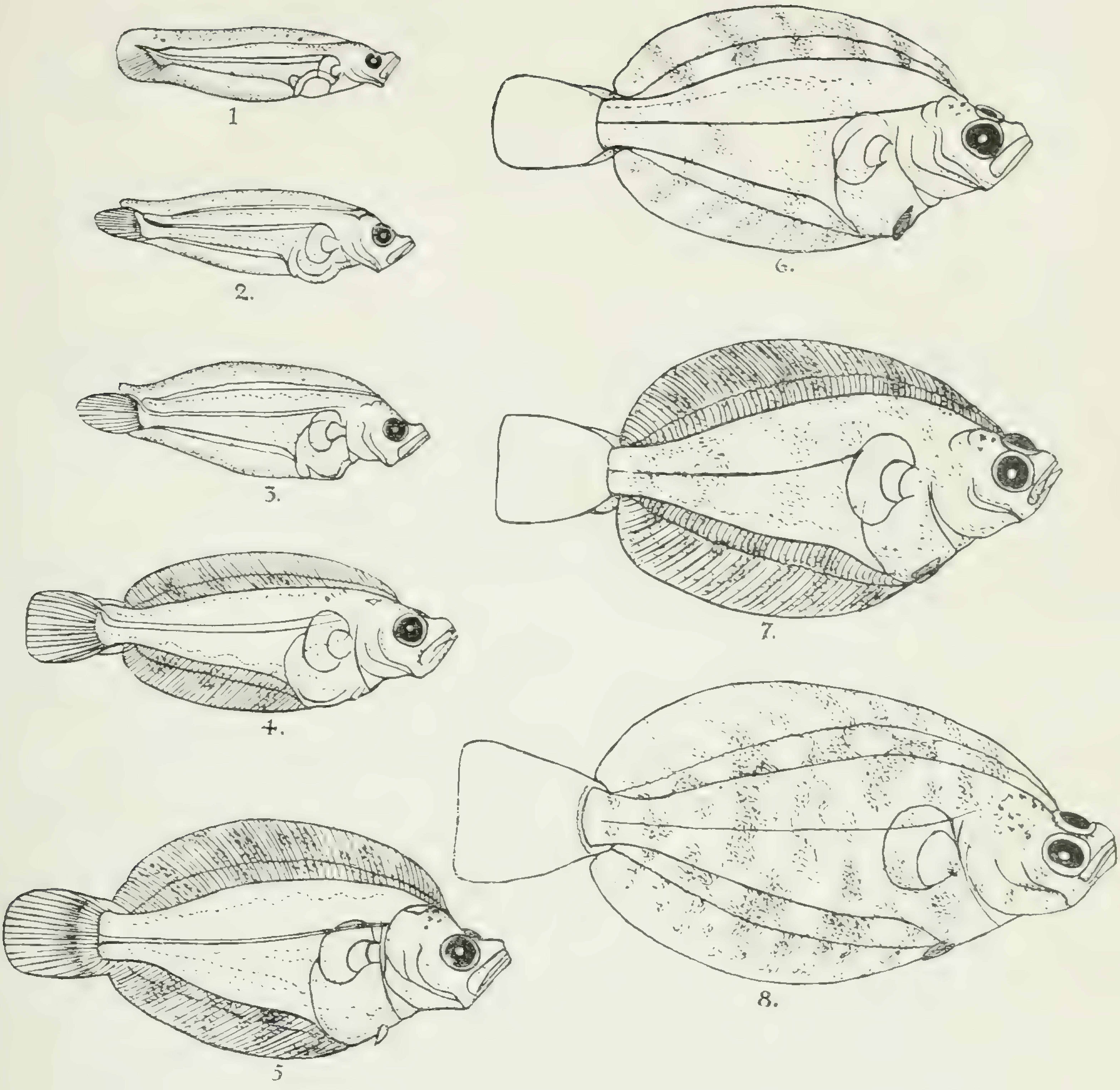


Fig. 1.—Hippoglossus hippoglossus, about $\frac{1}{2}$-inch long (May 22).
Fig. 2.— " " $\frac{3}{5}$-inch long (June 20).
Fig. 3.— " " $\frac{3}{4}$-inch long (June 20).
Fig. 4.— " " about $\frac{4}{5}$-inch long (June 19).
Fig. 5.— " " just under 1-inch long (June 19).
Fig. 6.— " " $1\frac{1}{12}$-inch long (June 20).
Fig. 7.— " " $1\frac{1}{5}$-inch long (June 19).
Fig. 8.— " " $1\frac{1}{3}$-inch long (July 9).

The above drawings are after Dr. Johs. Schmidt, Copenhagen (Meddel. f. Kommiss. for Havundersog. Fiskerei, Bd 1, 1904), and the specimens were obtained in 1904 off the west Iceland coast.

II.

NOTES ON THE EGG AND LARVAL STAGES OF THE HALIBUT.

By Professor Edward E. Prince, LL.D., D.Sc., F.R.S.C., etc.,

Dominion Commissioner of Fisheries, and International Commissioner (under the Fishery Treaty, 1908).

(With one plate.)

It is a well-known fact that the eggs of most of the important marine food-fishes, with such exceptions as the herring and the smelt, produce small buoyant eggs which float in the open sea, usually in the surface waters. They are so small that they escape notice, though in certain areas at the proper season of the year the sea within a fathom or two of the surface abounds with these floating eggs. As a rule, each egg floats single and separate, though occasionally, as in the angler or goose fish (*Lophius*) the eggs may be immersed in a long band or a mass of clear jelly-like substance and such egg bands are readily discernible in the open sea. In size, these floating eggs range from one-thirtieth to one-seventieth of an inch in diameter, and such vast numbers of them occur in the upper waters that a fine-meshed tow-net, of silk or cheesecloth, will secure great quantities; but, owing to their small size and colourless translucency, they may escape the notice of an ordinary observer. It is estimated that the eggs of over 250 species of marine fishes (*Teleosteans*) have been described, out of probably 80,000 to 90,000 species of fishes inhabiting the seas of the world.

RIPE HALIBUT EGGS DESCRIBED.

So far as is known, the largest of all these eggs is that of the halibut, yet it has more rarely been seen than those of any other species described by fish-embryologists. Ripe unfertilized eggs of the halibut have been obtaind five or six times during the last twenty-five years by marine biologists, the first being discovered by the leading European authority, Prof. W. Carmichael McIntosh, of St. Andrews, Scotland, who, in April, 1892, secured some ova from a ripe female halibut caught about 150 miles ENE. from Peterhead, Aberdeenshire. The eggs varied in diameter from one-sixth to one-eighth of an inch (3·07–3·81 mm.), or more than three times the size of the eggs of cod, haddock, or flounders. At the end of the same month Mr. Holt, who had been Professor McIntosh's assistant at St. Andrews, secured some halibut eggs at Grimsby, but though they were ripe and translucent they sank to the bottom when placed in a vessel of sea-water. Dr. H. C. Williamson later obtained ripe halibut eggs, and he noted the presence of a membrane-like covering, enveloping the yolk, quite separate from the external capsule of the vitelline membrane. In all cases the eggs were described as spherical, translucent, and clear, exhibiting no shining oily gloubles or other floating bodies in the ball of the yolk fluid. The outside capsule, as Professor McIntosh stated, was found to be extremely thin and marked with delicate "cross-hatching" or short intersecting lines. Indeed they easily collapse, when placed on a glass slip, after removal from water, being compressed by capillary attraction, and usually bursting. Most of these pelagic eggs, though so minute, transparent, and delicate, have some resistance, and can be gently rolled between the finger and thumb when, as Dr. Francis Ward said of plaice eggs, "they feel hard and shot-like," but the eggs of the halibut are unusually frail and collapsible.

ANNUAL SPAWNING PERIOD.

The spawning period of the halibut in the North sea appears to extend over many months. Dr. Williamson obtained some fully ripe eggs at the end of January, the parent fish having been taken about 145 miles out ENE. of Aberdeen, Scotland, the depth of water being 65 fathoms. Others have been noticed in March on the west coast of Scotland. Again, in the month of May, Dr. Williamson secured a quantity of ripe eggs from Viking bank, between Shetland and Norway, while Professor McIntosh studied ripe ova of halibut in April and May. The spawning period seems to range from January to August in different areas, for Dr. Brown Goode speaks of July, August, and even September as the spawning months on the Atlantic coast of North America; but Dr. J. B. Gilpin, a very diligent early observer, stated that it was in June he observed spawn running from ripe halibut of the Nova Scotia coast.[1] On the Pacific coast it would appear that the eggs are ripe in winter or early spring, as Professor Willey has pointed out in his paper, and the British Columbia Fisheries Commission, 1905-07, in their report, based on the evidence of British Columbia fishermen and others, recommended a close season from December 1 to March 31 each year, as appropriate. "A close season of four months in each year ....will rapidly restore the threatened halibut supply, and, enforced in the limits named, it will include all the 'banks' or spawning resorts in Hecate strait, etc., on to which the halibut move from the open ocean outside."

WHY FERTILIZED HALIBUT OVA NOT OBTAINED.

While the characteristics of the ripe unfertilized halibut egg have been fully described, and its recognition rendered an easy matter by the naturalist, no one has yet seen the fertilized or developing egg in the open sea, or has succeeded in obtaining ripe male and female halibut and artificially fertilizing and incubating the ova. In the pioneer investigations into the life-history of marine food-fishes, in which I was privileged to take a considerable part twenty-five years ago, two methods were adopted for the discovery and diagnosis of fish eggs and young. Eggs naturally spawned and fertilized were obtained by fine-meshed tow-nets floated near the surface of the sea, and these were studied and detailed drawings made, and the species determined by a comparative method, or the specialist obtained living fishes of both sexes from the fishing grounds, extruded the ripe eggs and fertilized them by the usual methods of fish-culturists, and hatched out the young fry in the tanks of a marine laboratory. In this way a body of knowledge was accumulated by the early investigators which has been invaluable for succeeding workers. In the case of the halibut the floating eggs have not yet been secured by tow-nettings, and Professor Willey, in the preceding paper, has ventured the suggestion that the eggs float at some depth, not near the surface, as do the eggs of the Argentine (*Argentina silus* Asc.) of the North Atlantic, which are of large size, 3 mm. to 3·5 mm. in diameter, and occurring in oceanic strata far from the surface, according to Dr. Schmidt. The fact that the eggs of the halibut must be very abundant in northern Atlantic and Pacific waters and yet none have been obtained in a developing condition in the sea, strongly supports Professor Willey's important suggestion.

DIAGNOSTIC FEATURES OF TWO SPECIES OF HALIBUT.

The earliest larval stages of the halibut are not yet known, and cannot be accurately made known until fertilized eggs are studied and the young fish hatched out and reared, as has been done in the case of such a great variety of marine food-fishes. At various times, small larval fishes have been captured in the sea, which were pronounced as most probably young halibut. In most of these cases later research has

[1] Food Fishes of Nova Scotia, Art. II, p. 23, Trans. N.S. Inst. of Sci., 1868. A United States expert recently stated that an Oregon halibut on September 1, 1914, contained large loose eggs and more nearly approaching ripeness than any female specimen obtained previously, hence the spawning period could not be far off.

proved the diagnosis incorrect. Thus, Dr. H. M. Kyle, an able original worker in this field of research, described two larval flat fishes, 12 and 14 mm. in length, respectively, secured in August in the Moray Firth, Scotland, and regarded as probably larval halibut, though it was also thought that they might prove to be young pole-dab (P. cynoglossus). The description and published drawings (Plate iii, Journ. Mar. Biol. Assoc., Plymouth, vol. vi, No. 4, December, 1903) attracted the attention of specialists and resulted in favour of the latter determination, and Dr. Kyle, in a final foot-note (*ibid.*, p. 621), said: "At first I was disposed to regard them definitely as young halibuts, but from a drawing sent to him, Mr. E. W. L. Holt is inclined to regard them as pole-dab." Similarly, the staff of the United States biological steamer *Albatross*, regarded four specimens of flat fish as halibut which had been captured 60 or 70 miles off the New Jersey coast (39:45 N. lat., 73:49 W. long.) about the end of May, 1887, at the surface of the sea; but they were clearly not halibut, from certain diagnostic features which they presented. Thus they showed coloured transverse bands, and the dorsal fin possessed about 80 rays, though the fish were only 17 mm. long (seven-tenths inch), whereas the halibut does not exhibit a transverse arrangement of pigment spots until it is much larger, 27 mm., or over an inch long, and rarely fewer than 100 fin rays in the dorsal fin. The two species of halibut now recognized, viz., *Hippoglossus hippoglossus* Linn. (or *H. vulgaris* Flemming) has 90 to 103 rays in the dorsal fin, and *Platysomatichthys hippoglossoides* Walb., has 96 to 108 rays in the same fin. Conjointly with other features, if any specimen has 100 rays or more it is unquestionably a halibut. But the number of joints or vertebrae in the backbone is even more distinctive, for *H. hippoglossus* has usually fifty, and *P. hippoglossoides* has sixty-two vertebral elements, and the anal fin, it may be added, has seventy-one to eighty-three rays in the former and sixty-seven to seventy-nine in the latter species. The well-known specimen of supposed halibut procured by Dr. C. G. S. Peterson, of the Danish Zoological Station, in the waters of Christiansund is now known, like that of Dr. Kyle, to be almost certainly a specimen of the witch or pole dab. It was 32 mm. (1⅜ inch) in length and had 104 rays in the dorsal fin, eighty-eight in the anal, and twenty-two in the caudal, and the gill cover exhibited a row of spines. This last feature is one which demonstrates the specimen not to be a halibut. Dr. Peterson's larger specimen obtained in Greenland in 1893 in May and measuring 51 mm. (over 2 inches) in length has seventy rays in the anal fin, but the halibut has more rays—not less indeed than seventy-three rays in *P. hippoglossoides*[1], and eighty-two to eighty-three in *H. hippoglossus.*

YOUNG LARVAL HALIBUT DESCRIBED.

It is due to the accomplished Dr. Jos. Schmidt, the Danish biologist, that the youngest stage of the halibut obtained up to the present has been determined. The specimen was 13·5 mm. long, over half an inch (or ·531 in.) and it had still the worm-like form and symmetrical upright position of the early larva (Pl. I. fig. 1). All the flat fishes (Heterosomata) undergo a transformation before they lie permanently on one side with both eyes on the same surface. "Flat-fish larvæ," as Dr. Ward says, "begin by swimming near the surface in an upright position like the larvæ of other fishes. Next, they flatten from side to side, and gradually approach the bottom, to end up by lying on their right or left sides as the case may be. . . . Plaice, soles, bounders, dabs, lemon soles, and halibut, after they have flattened, all lie on their left side, while turbot and brill lie on their right side." One eye moves to the other side as the transformation proceeds, so that both eyes are found on one side of the fish in the permanent flattened condition. Thus the halibut, when it hatches out of the egg,

[1] Dr. Gilpin, of Halifax, gave the number as seventy-four or seventy-five rays (loc. cit., p. 21) for Nova Scotia specimens.

has an eye upon each side of the head like the cod, haddock, herring, and all "round" fishes, and until it is 18 or 20 mm. (seven-tenths to eight-tenths inch) long shows little indication of the tendency to the flattened form so characteristic of the later stages.

The description which is here given refers mainly to the common species in the Atlantic and North Pacific ocean, viz., *Hippoglossus hippoglossus* but the differences between the two species in their young larval stages are not apparently very marked.

The larval halibut, about half an inch long, is a long slender little fish, with a snout slightly upturned and obtuse or flattened in front, quite unlike the flounder, sole, and other pleuronectids. In most of these flat-fishes the snout is rounded and curves downward, often with a sharp-hooked tip as in the sole (*Solea vulgaris*); but the snout of the larval halibut is flattened in front, slightly upturned and "pig-like." There is a marked depression between the eyes and the abrupt tip of the snout. The minute spots of black pigment present in the youngest stage known, viz., 13·5 mm. (·53 inch), are arranged in four indefinite rows along the caudal trunk behind the anus, also a series along the dorsal line and along the ventral margin at the base of the larval fin from the pectoral region posteriorly. On the larval fin membranes themselves scattered dots occur near the margin of the dorsal and ventral median fins. The dots cease as these fins merge in the terminal tail fin. The upper and lower jaws are very straight not curved as in some species and instead of bending downward, they turn upward at an angle of about 60 degrees and the mandibular articulation projects prominently in a characteristic manner. The eyes are large, silvery, and pigmented in all stages known, and the pectoral fins are well-developed. When about one-fifth longer (Pl. I. fig 2), very minute scattered spots of a reddish colour appear between the myotomes or serial muscle masses of the body and give a faint reddish tinge to the little fish when viewed by the naked eye. The large silvery eyes acquire a bright blue tint and show very prominently. The next stage 22 to 23 mm. (·83 inch) long is marked by the appearance of three groups of black spots or dark bands on the dorsal and ventral fins which are now supported by fin-rays, these rays being short and rudimentary in the previous stage. The spots on the body assume the form of very distinct wavy lines and the left eye begins to migrate from its position and is just visible as a slight projection in the depression on the head (or rather forehead). The fish has now a very characteristic halibut outline.

When a length of an inch is reached (24½ mm.) Pl. I. fig. 5, the groups of spots in transverse bands on the dorsal and anal median fins are more complex. Between the four main stripes, three smaller bands appear, so that at least seven stripes or bands can be counted upon each fin-expansion. This stage (Pl. I. fig. 6) is reached before the end of May, according to Dr. Schmidt, who obtained specimens on May 25 in water of 116 metres (60 fathoms).

Nearly a month later a size of about 30 mm. (1⅕ inch) is reached, and the left eye projects to the extent of about half of its mass above the contour of the forehead, and the coloured bands (the broad and the narrower secondary bands) are a still more marked feature on the dorsal and anal fins, while the spots on the side of the body form four fairly distinct transverse bands (Pl. I. fig. 7). On reaching a length of 34 mm. (Pl. I. fig. 8) the fish still swims in the upright position, but the right side is darker, more pigment being developed than on the left side of the fish. The patches of colour lose somewhat the transverse arrangement and mingle irregularly, producing a marbled pattern, which is very characteristic of the young halibut for a considerable subsequent period. It is noteworthy that two rounded patches appear near the base of the tail. Up to this stage the tail was transparent and clear and free from any pigmentation. Dr. Schmidt obtained this stage on July 7 in a depth of 44 metres (24 fathoms). The next stage recorded is that of Dr. Peterson, who secured an alleged halibut 51 mm. (2 inches) in length about the end of May in water 500 fathoms in depth. He noted that it has seventy rays in the anal fin, but the rays in the dorsal fin are not recorded. When a length of 120 mm.

(about 5 inches) has been attained, the features of the full-grown halibut seem to be assumed, and the subsequent changes are those pertaining to size and sexual development. Professor Verrill got a small halibut of this size in a dredge when investigating the Strait of Canso waters many years ago, and this is the smallest specimen obtained on North American shores.

OLDER EXAMPLES OF SMALL HALIBUT.

Halibut about 10 inches long (20 cm.) are common in shallow waters around Iceland, and Professor McIntosh has recorded Scottish specimens 12 inches long, in shallow areas such as St. Andrews bay.

It is apparent from the little evidence available that halibut, after passing through their larval and post-larval metamorphoses in deep water, frequent inshore shallows during part of their adolescence, when the dull olive colour of the dark right side of the fish is marbled with the meandering dark bands which characterize it at so early a period as the 1⅓-inch stage. Comparing the common species with *H. hippoglossoides* specialists have found that in the two youngest known stages no pigment whatever appears, and in the larger stages (51 mm.) the colour spots on the body are sparse as contrasted with the other species at the same size. No doubt much pigment may have been lost, and in the youngest specimens removed completely through the action of the preservative fluid in which such specimens are placed for purposes of scientific study.

Immature halibut do not appear to frequent any special depths, and Dr. Gilpin long ago pointed out that specimens the size of the outspread hand are got in Nova Scotia weirs and traps, close inshore, and occur also in plenty on the "banks" in the open sea.

Dr. Wemyss Fulton obtained a halibut 7⅜ inches long in Aberdeen bay on November 1 some years ago, the depth being 8 to 18 fathoms, and one off Dunbeath (Caithness) 11¾ inches, while a specimen 14 inches long (weight, 15½ ounces) was secured in Dornoch Firth in December.[1] His opinion is that in July, August, and September these small halibut move off into deep water, and in October he records specimens from 17½ to 30 inches long in 65 fathoms depth, though Captain Collins, the well-known United States authority, records halibut of three pounds weight in October, 1886, on Jeffrey's ledge, off the New England coast. The migrations of these immature and of the large mature fish afford a complex and interesting problem for future investigation.

[1] 21st Ann. Rep., Scott. Fish Bd., 1902, p. 53.

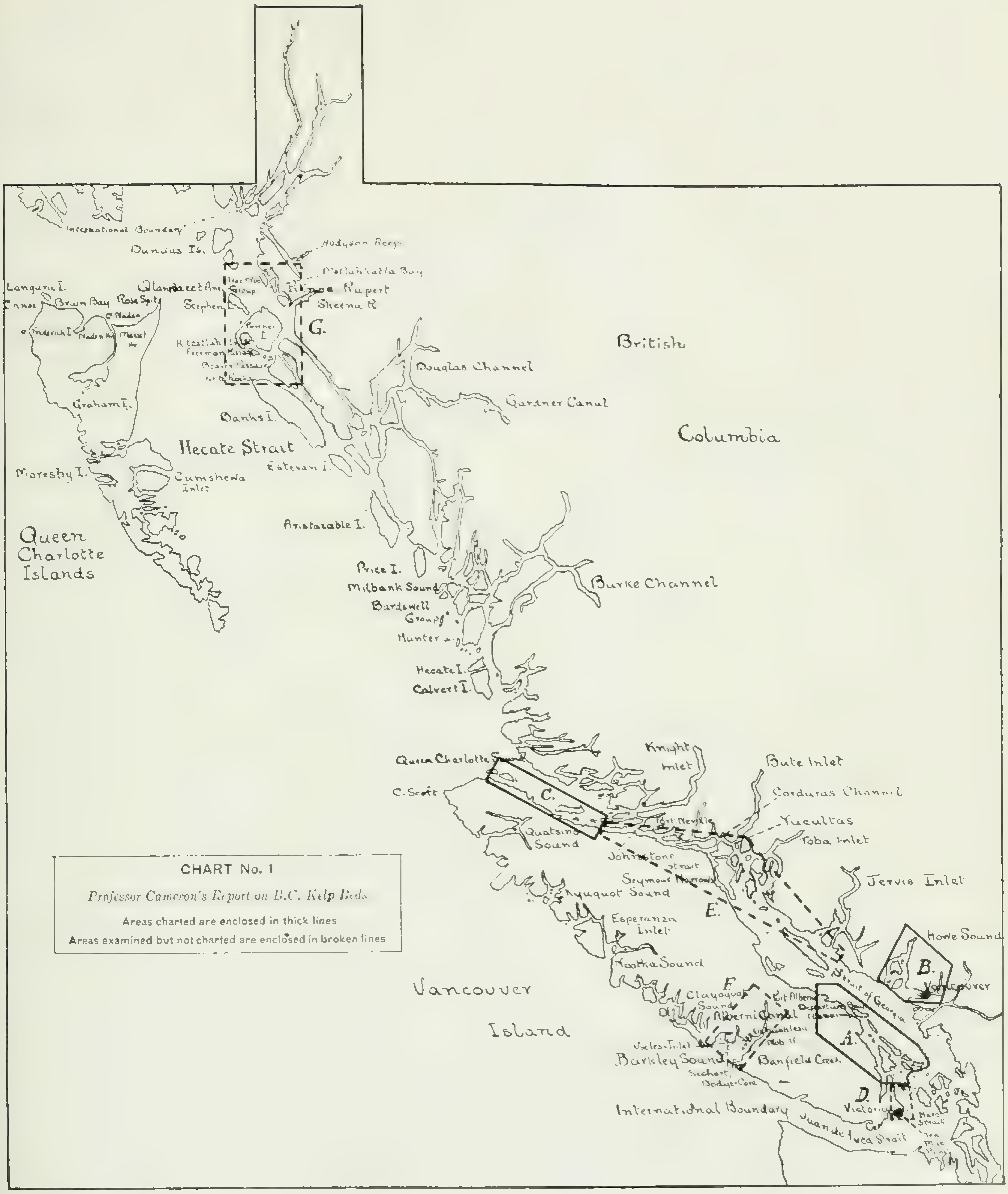


CHART No. 1

Professor Cameron's Report on B.C. Kelp Beds

Areas charted are enclosed in thick lines

Areas examined but not charted are enclosed in broken lines

III.

THE COMMERCIAL VALUE OF THE KELP-BEDS OF THE CANADIAN PACIFIC COAST.—A PRELIMINARY REPORT AND SURVEY OF THE BEDS.

By A. T. Cameron, M.A., B.Sc.

Assistant Professor of Physiology and Physiological Chemistry, University of Manitoba, Winnipeg.

(With Three Charts.)

Kelps and other seaweeds have been extensively used for a long period as fertilizers. In the British Isles, Norway, and the coast of Brittany, and along the Atlantic coast of Canada and the New England coast they are collected, when washed ashore during storms, and spread as manures without further treatment.[1] The Pacific kelps are also used to a slight extent in the Western States in the same way.

Iodine was for a long time prepared commercially in considerably quantity in Scotland from various species of seaweed. Its preparation as a by-product in the nitre industry has caused the original industry to languish; little iodine is now prepared from seaweed.

The principal fertilizing constituents of seaweeds are potassium chloride and phosphates. Direct application to the soil involves the loss of iodine, one of the most valuable constituents.

The control of the world's supply of potassium has within recent years been held by the Stassfurt Potash Syndicate, which completely controls the German mines, and which has dictated both the annual supply, and the price to be paid for it. This price has not diminished, there being a steadily increasing demand.

The outbreak of the present war has emphasized this dependence on Germany for potash supplies. The source is at present cut off. Other sources must be sought for. The market quotation for raw potassium chloride held steadily at $39.07 for many months previous to August 1914, when the year began. There is no quotation for September.

In addition to its use as a fertilizer, potash is required for many other purposes. A recent quotation from *Science*[2] dealing with the effect of the war, reads: "Potash salts are employed in many industries other than the fertilizer industry. A large amount is used in glass and soap making and in the manufacture of a number of chemical products. These include potassium hydrate, or caustic potash, and the carbonate and bicarbonate of potash, used principally in glass and soap making; the potash alums; cyanide, including potassium cyanide, potassium ferrocyanide, and potassium ferricyanide; various potash bleaching chemicals, dyestuffs, explosives containing potassium nitrate, and a long list of general chemicals. The imports of potash salts, listed as such in the reports of the Bureau of Foreign and Domestic Commerce, include the carbonate, cyanide, chloride, nitrate, and sulphate, caustic potash, and other potash compounds."

---

[1] An account of the present utilization of kelp in the United Kingdom is given in the United States Consular and Trade Report, Tuesday, June 9, 1914, pp. 1402-5 (Bureau of Foreign and Domestic Commerce, Department of Commerce, Washington).

[2] *Science*, August 28, 1914, vol. 40, p. 310.

The far-reaching effect of a stoppage of all potassium imports may be exemplified by the fact that to work low-grade gold ores requires a large supply of potassium cyanide.

The *Science* article reads further: "The importation of the above salts in round numbers during the last three years has averaged 635,000,000 pounds in quantity and $11,000,000 in value. The figures . . do not include the imports of kainite and manure salts, which are used as fertilizers. The quantity of this class of material imported during the last three years has averaged about 700,000 tons valued at $4,300,000 annually. Thus it is apparent that the annual importations of potash salts exceed $15,000,000." These figures, of course, apply to the United States.

While the amount of potassium fertilizers at present imported into Canada is small, those of the potassium salts are of the same order per head of population as those for the United States, and show a steady marked annual increase. The figures following are calculated from the Report of the Department of Trade and Commerce (Ottawa) for the fiscal year ending March 31, 1913, Part I.

The imports include crude potassium hydrogen tartrate (cream of tartar), cyanide of potassium (and sodium), bicarbonate, bichromate, chlorate, chloride, sulphate, nitrate, ferrocyanide, and hydrate of potash. The total imports of these salts for the fiscal years 1912 and 1913 are, respectively, 5,585 and 7,440 tons; the respective values for the years 1909-13 are: $496,704, $515,501, $610,455, $703,711, $848,759. In addition potash salts for fertilizers were imported to the respective values of $7,993, $7,284, $5,921, $6,995, $252. It may be further noted that the corresponding figures for crude iodine imports are $25,751, $24,241, $15,081, $16,866, $23,712, the average yearly import being $21,138. The average total import of these commodities is therefore $661,847, but it is to be noted that the largest of the above items shows such a steady marked increase that the figure for the year just completed (which is not yet available) is probably about $1,000,000.

It is evident that it is highly important to ascertain whether there are any sources of potash salts in Canadian territory, whether these are sufficient to supply our own necessities, and whether any surplus can be profitably marketed.

The United States, having realized their dependence on outside sources for potassium salts, have been studying the problem for some years. The results of their initial inquiry were published in 1912 (F. K. Cameron and others, "Fertilizer Resources of the United States," Senate Document 190, 62nd Congress, 2nd Session, 1912). Since that time they have carried out much more extensive investigations, and Congress voted, during the past summer, $7,000 for the publication of the complete results. Their investigators have found that while certain mineral sources were available, and could be probably worked and supplied profitably over a limited area, by far the most extensive sources of potash were the large beds of different kelps growing along their Pacific coasts. Accordingly, these have been completely charted.

Last year I drew the attention of the Biological Board of Canada to some aspects of this problem, and this year was asked by them to carry out a preliminary investigation of the kelp beds of the Canadian Pacific coast. The results of this investigation follow.

NATURE OF THE AVAILABLE KELPS.

Most of the larger sea plants belong to the family *Laminariaceæ* of the *Phæophyceæ* or brown seaweeds. The distribution of *Laminariaceæ*, which include all the so-called kelps, along the shores of the strait of Georgia (which separates the British Columbia mainland from Vancouver island) is exemplified by those species observed in the neighbourhood of Nanaimo, B.C. Here are found: *Laminaria saccharina, Laminaria bullata, Costaria turneri, Agarum fimbriatum, Alaria tenuifolia, Nereocystis lütkeana* [along with two rock-weeds, belonging to another family, *Fucus evanescens*, and *Fucus furcatus* (*inflatus*)]. I have seen also, cast up on a storm-swept bay on

the north side of Hope island, off the north coast of Vancouver island, *Nereocystis lütkeana*, *Macrocystis pyrifera*, *Alaria* (a second species), *Egregia menziesii*, *Cymathære triplicata*, and *Hedophyllum*.

Of all these, only *Nereocystis lütkeana* and *Macrocystis pyrifera* are of economic importance. The other *Laminaria* are not present in large beds. The *Fucaceæ*, while abundant, could only be collected by hand, and conditions of labour along the Pacific coast therefore negative any idea of their utilization. Furthermore, their potash content is much smaller than that of the two kelps. These, from their nature, can be harvested by mechanical means, and hence at a much smaller cost.

Nereocystis lütkeana, commonly called bull-kelp, or simply kelp, consists of a long stalk or stipe, much branched below into the "holdfast" attaching it to a small rock or rock-crevice several fathoms below the sea-surface, and distended above into a hollow bladder, the "*pneumatocyst*," containing air. To this are attached numerous long fronds which are kept near the surface of the water by means of this float. *Nereocystis* is found growing at depths varying from 1 or 2 to 10 or more fathoms. Most of the *Nereocystis* that I have examined has been growing at depths of from 4 to 6 fathoms (24 to 36 feet). The length of the plant varies considerably. The longest plant that I measured was 63 feet in length. This was obtained near Haro strait, just north of the Puget Sound region. In the latter, Rigg states that he found no specimens over 70 feet in length[1], although elsewhere much greater lengths have been recorded. Much larger plants are also met with in British Columbia waters. Mr. A. Lucas, fishery overseer at Alert bay, informs me that he has obtained a plant on Nawhitti bar, off the North coast of Vancouver island, measuring 111 feet in length.

Nereocystis lütkeana is found more or less extensively throughout British Columbian waters.

Macrocystis pyrifera is, according to Setchell, known as "long bladder kelp."[2] I have found in use the more descriptive terms "sea-ivy" and "flag-weed." The plant consists of a holdfast of many whorls, from which extend upward usually numerous stipes, each of which carries at regular intervals large ivy-leaf-shaped fronds, joined to the stipe through a buoying bladder. The length of the plant is variable. Off the Californian coast plants 150 feet in length have been met with. Rigg states that 50 feet is the common length in the Puget Sound region. I have found plants 40 to 50 feet in length in Barkley sound (west coast of Vancouver island) and 30 feet or less off the north coast of Vancouver island and off Banks island. A diminution of mean temperature may determine this diminution of length.

Macrocystis pyrifera has been reported off Victoria and Port Renfrew. I have found it in Barkley sound, along the north coast of Vancouver island, off Banks island, and in Qlawdzeet anchorage, Stephen island, so that it is evident that it is present along the whole coast of British Columbia. This was to be expected, since, while common farther south, it is also not uncommonly met with in Alaskan waters. It is not present in the inner coastal waters of British Columbia, from Ten-mile point, near Victoria, to Port McNeill. Its absence in these waters must be attributed to their lessened salinity.

CONDITIONS AFFECTING THE GROWTH OF "NEREOCYSTIS" AND OF "MACROCYSTIS."

The factors determining the growth of *Nereocystis lütkeana* and *Macrocystis pyrifera* are the same:—

(1) A suitable rocky surface of attachment.
(2) A marked movement of the water containing the plant.
(3) A suitable salinity.
(4) Not too high a temperature.

1 "Fertilizer Resources of the United States." Senate Document 190, 1912, p. 180.
2 *Ibid.*, p. 159.

(1) The most suitable surface of attachment for kelp consists of a stony or rocky bottom at a depth of from 3 to 6 or 8 fathoms (in Canadian waters). Most of the large plants of kelp that I have seen were growing in from 4 to 6 fathoms of water (low-tide measurement). Apparently the nature of the rock has something to do with the result, presumably through the surface it possesses. Sandstone and limestone rock-bottoms are usually devoid of kelp. Conglomerate and granite are favourable. Kelp need never be looked for along sandy or shingly shores, nor where there is a mud bottom.

(2) Kelps flourish most luxuriantly where there is a maximum tidal current of from 3 to 5 knots an hour. Beds are found where there is much slighter water movement, but, generally speaking, the less the movement of the water, the less luxuriant is the kelp growth. I have observed no growth of kelp where the "tide-rip" reaches a maximum of 6 or more knots an hour. Apparently *Macrocystis* grows preferably in somewhat stronger currents than *Nereocystis* (see the remarks on the kelp growth in Barkley sound and off Banks island below).

Salinity is one of the chief determining factors of the growth of kelp. It does not grow in brackish water (see the results for Howe Sound, etc.). *Nereocystis* can apparently attain a moderate size in water of less than two-thirds ocean salinity (mean density 1·019) and where the salinity occasionally sinks temporarily to much lower values (density 1·013, for example), but both length and weight increase distinctly with increased salinity, as will be shown below. *Macrocystis* does not grow at all until a higher salinity is reached. While *Macrocystis* has been observed in Barkley sound, with density of the containing water as low as 1·0185, too few readings were taken to determine the average value with accuracy (1·0195 for three readings). The average of readings off the north coast of Vancouver island, where *Macrocystis* is common, was 1·022, and the lowest figure observed 1·021.

(4) The effect of temperature is less certainly demonstrable. According to Setchell,[1] temperature is one of the chief factors affecting the distributing of different species, but there seem to be no available data bearing on the effect of temperature on the growth of particular species. In sheltered bays in the strait of Georgia, where local bodies of water attain a moderately high temperature (60° to 65° F.) for a month or more at the height of summer, disintegration of *Nereocystis* appears to commence sooner than usual.

LIFE-HISTORY OF "NEREOCYSTIS" AND "MACROCYSTIS."

Nereocystis is a yearly plant, growing rapidly in spring, reaching maturity in July or later, and then decaying at a greater or less rate. Many plants are torn away from their anchorages, and the beds considerably depleted in this way with the onset of winter storms. Others probably decay till the pneumatocysts burst, and the plants then sink. The beds are thickest from July to September or October. Many are probably visible throughout the year, the young plants attaining some size before the older plants have completely disappeared.

The plants are propagated asexually by spores. The exact time at which the spores are set free is a matter of importance, since it must be taken into consideration in fixing the best time to cut the beds. According to Rigg,[2] kelp plants can be cut after July 15 without interfering with spore-discharge and so with next year's crop. This conclusion is based on observations in the Puget Sound region. As far as I could judge, in more northern waters the plants reach full size at a slightly later date, and it might be desirable to defer cutting until a somewhat later period. More information is required on this point.

---

[1] Setchell, *ibid.*, pp. 135-137.
[2] Rigg, *ibid.*, p. 186.

Macrocystis has a life longer than a year, and exact data as to its rate of growth and rate of regeneration (for the plant is said to regenerate when cut) are at present not available. Spore discharge takes place from sori situated on fronds low down on the plant towards the base, so that the greater portion of the plant can be removed without interfering with reproduction.[3]

During 1913, observations were made by the American Bureau of Soils at La Jolla and Point Fermin, California, and at Friday Harbour, Washington, on the life-history of *Nereocystis* and *Macrocystis*, with especial reference to cutting and harvesting.[4] The results will presumably appear in the report in process of publication already referred to.

THE ECONOMIC VALUE OF THE PACIFIC KELP BEDS OF CANADA.

This investigation has been directed with two aims. An estimate—very approximate, of course—was sought of the total amount of kelp available for commercial purposes, and a further estimate of what part of this could be harvested at a probable profit.

The kelp beds do not attain full size before the middle of July at earliest. Investigations were commenced, however, at the beginning of the month, and carried on until the end of August. Since, in that limited time, only a relatively small portion of the coast line could be examined accurately, typical portions were mapped out, so that from these the average yield per mile of coast line might be calculated with at least an approximation to accuracy. The portions examined will be seen on reference to Chart I. The following districts have been charted as accurately as time would permit:—

A. The district comprising the southeast coast of Vancouver island, from Northwest bay to the north of Saanich peninsula, and the islands to the east of this from the Ballenas group to the international boundary.

This district can be regarded as typical for waters of moderate salinity, abounding in reefs. It comprises 500 miles of coast-line.

B. The district included in Howe sound and Burrard inlet. These are typical of the large inlets comprising some thousands of miles of coast-line, and occurring at regular intervals along the mainland.

This district can be regarded as typical for brackish waters. The part mapped includes about 200 miles of coast-line.

C. The district along the north coast of Vancouver island from Hope island to Baronet passage.

This district is typical for waters of fairly high salinity; it comprises 240 miles of coast-line.

The following districts were examined:—

D. The coast-line of Vancouver island and the islands adjacent, south of district *A*, to Victoria.

E. The channels between Vancouver island and the mainland, from Texada island northward to Johnston strait.

F. Barkley sound and the Alberni canal (selected as typical of the inlets on the west coast of Vancouver island).

G. The district from the north of Banks island to Prince Rupert and Hodgson reefs.

---

[3] Setchell, *ibid.*, 9. 139.

[4] Phalen, "Potash Salts for 1913," p. 93 (Publications of the U. S. Geol. Survey).

An attempt was made to examine the beds along the shores of the Queen Charlotte islands. I succeeded in reaching Rose Spit in the D.G.S. *Malaspina,* in a southeaster, but after remaining there for thirty hours without abatement of the weather, the steamer had to proceed south to Esquimalt on the outbreak of the war.

The observations were carried out in the various steamers and gasolene launches of the Fishery Service, and my thanks are due to Chief Inspector Cunningham, Inspectors Taylor and Williams, and the officers in charge of the boats of that service, and to Capt. Holmes Newcomb of the *Malaspina* for rendering me every assistance in their power in order to carry out this work successfully.

The launch at the Biological Station was also used for local work, and I have to thank Dr. Maclean Fraser, the curator at the station, for continued assistance and valued advice. He also surveyed for me the district from Nanoose bay to the Ballenas islands, included in *A*.

In carrying out such work as the above it may be noted that indications given in the Admiralty charts of the presence of kelp are as a rule accurate, kelp seldom being found in quantity except where marked on the charts. The charts give no clue, however, to the extent of the beds.

The results of the examination will now be summarized, district by district.

Method of Examination.—Only a rough approximation has been attempted; this is undoubtedly a conservative one. Beds were considered as thin, or thick. Thin beds were estimated to contain an average of one plant per square yard. Thick beds were estimated to contain three or more plants per square yard (often the beds were decidedly thicker than this). The widths of the beds were estimated roughly and noted.

In addition, fringes close inshore were noted, and were considered about 5 yards wide, and thin or thick as before. Such fringes total to only a small percentage of the whole amount.

Several typical plants of typical beds were weighed to give the average weight per square yard. The parts weighed included the fronds, pneumatocyst, and 8 or 10 feet of the stipe, this being the probable amount removed by any mechanical system of cutting.[1] The calculations have been based on the weights and thickness of *Nereocystis* plants only. It is more difficult to estimate the thickness of beds of *Macrocystis.* The weights obtainable in any given area are probably of the same order for the two species. In any case the great majority of the kelp beds in British Columbia waters consist of *Nereocystis.*

Knowing the extent of the beds, the number of plants per square yard, and the average weight of each plant, the weight of the kelp in any area can then be at once calculated.

District A.—The actual survey of the district was made between the dates July 6 and 10, inclusive, a preliminary examination having been made in the previous week. The results of the survey are shown in Chart II.[2] Plants were weighed each day with the following results:—

---

[1] Various measurements indicate that the remainder of the stipe and the holdfast weigh from 50 to 70 per cent of the weight of pneumatocyst plus 8 or 10 feet of stipe.

[2] Map II is taken from Admiralty Chart No. 579, to which it should be referred.

Place obtained.	Total length.	Average length.	Weight of fronds.	Weight of pneumatocyst and part of stipe.	Total available weight.	Average weight.
	feet.	feet.	lb.	lb.	lb.	lb.
1. Shoal Harbour (inshore in shallow water).	44		0·5	1·5	2	
	39		4·5	1·5	6	
	35		4·5	2	6·5	
	29	37	3	1·5	4·5	5
2. Channel between Comet and Gooch islands.	63·5		15·5	4·5	20	
	51·5	57·5	23	6	29	24·5
3. South end of Prevost island........	45		11	3·5	14·5	
	42		6·5	1 5	8	
	41·5		9·5	3	12·5	
	41·5	42·5	9·5	2	11·5	11·5
4. Belle Chain........................	57·5		8·5	2·5	11	
	43		5·0	2·5	7·5	
	38	46	9·5	2	11·5	10
5. On Gabriola reefs.............	29·5		6	1	7	
	28·5	29	7·5	2	9·5	8

Allowing equal value for each average, these figures give an approximate average of 12 pounds per plant (portions available for removal).

Using this figure, from the data furnished in map II, I estimate that 122,760 tons of kelp could be obtained from this district, giving an average of 245 tons per mile of coast line.

Throughout this and succeeding surveys, measurements of the density of the sea-water holding these beds were made at frequent intervals. These and other data are publish conjointly with Dr. Maclean Fraser on later pages, and have led to the conclusion that in the northern part of this district there is a noticeably smaller mean salinity value than in the southern (due to influx of fresh water from the inlets of the mainland and the Fraser river), the density figures being, respectively, 1·019 and 1·021.[1] Corresponding to this, the southern portion (Haro Strait region, connected to the open ocean through the strait of Juan de Fuca—see Chart I) has a much greater growth of kelp, as shown in the following figures. These are calculated on the assumption that the weight throughout is 12 pounds per plant. The table just given shows, however, that a higher value was obtained for plants farther south, so that the differences shown below are probably actually greater.

(1) District south of Saltspring island (coast-line 60 miles), 34,140 tons of kelp, being 570 tons per mile.

(2) District north of this limit (coast-line 440 miles), 88,620 tons of kelp, being 200 tons per mile.

The remaining conditions (kind of sea-bottom, tidal currents, temperature) were not markedly different. Chart II clearly shows the increased growth in the southern area.

All the kelp seen in district A was *Nereocystis lütkeana.*

District B.—In Howe sound there is no kelp. In Burrard inlet there is a single patch of *Nereocystis* an acre or less in extent in Vancouver harbour; this is negli-

[1] The extremes probably show greater differences, though too few readings were taken in the southern portion to lay great weight on them. Those observed were: Northern portion, 1.011 to 1.022; southern portion, 1.020 to 1.022.

gible. (The observations were made on August 19.) The absence of kelp in Howe sound is traceable to several causes, each probably in itself sufficient. The shore is sheer, a depth of 60 fathoms or more being reached a few feet out. The rocks are of carboniferous limestone, affording no hold for kelp, even were there any ridges at a suitable depth below the surface. The whole of the water of the sound is brackish, a large amount of fresh water being contributed by the Squamish river, flowing into the head of the sound. Density measurements taken within 3 miles of the head of the sound showed fresh water. Measurements 23 miles farther out (just outside the sound itself, in the strait of Georgia) showed a density of only 1·008. It may be pointed out here that since kelp grows near the surface, and since the greater part of the plant remains within 2 or 3 feet of the surface, it must be particularly subject to the influence of the surface water, so that measurements of the density of this give a clue to the salinity of the sea-water actually affecting the plants.

The conditions in Burrard inlet are somewhat similar to those in Howe sound, but the amount of fresh water flowing into the inlet is less, and the mean density value of the surface water higher. The combined coast-line of Howe sound and Burrard inlet is about 200 miles. The situation of this district can be seen by reference to Charts I and II. Off the extensive sand flats at the mouth of the Fraser river (see Chart II) no kelp is to be expected. I have not examined these flats myself, but have been informed by numerous persons that no kelp exists along this strip of coast.

Howe sound is typical of most of the large inlets farther north, both as regards the brackishness of the water, and the sheerness of the shores. I am informed that no kelp exists in any of them, except perhaps along the islands at their mouths. District B can, therefore, be taken as representative of a very considerable amount of coast-line.

District C.—The district north of Vancouver island is much richer in kelp than District A. The part surveyed is shown in Chart III, and the work was carried out on July 23 and 26, inclusive. An attempt was made to see the kelp on Nawhitti bar, to the west of the portion charted. There are vast beds here for more than 10 miles, indeed most of the way to cape Scott, and the kelp grows to a much greater size than on the less exposed portion actually seen. The weather conditions were unfavourable, and I was unable to see this region. In order to chart this mass of kelp properly it may be necessary to stay a week or longer in Bull harbour, Hope island, and seize a favourable combination of calm weather and slack low water. It should be noted that in order to survey many of the beds properly it is necessary to see them under these conditions; this materially hinders rapid work. Rough water hides the kelp considerably and prevents an accurate estimate of its extent. The kelp grows most luxuriantly in a "tide-rip," and this when in action drags it under, and may almost completely submerge large beds.

In order to estimate the weight of kelp available in this district sample plants were taken from a very large patch north of Haddington island with the following results:—

Total length.	Average length.	Weight of fronds.	Weight of Pneumatocyst and part of stipe.	Total available weight.	Average weight.
feet.	feet.	lb.	lb.	lb	lb.
61		18·5	6	24·5	
56·5		16	5·5	21·5	
53		8	4	12	
51·5		13·5	4·5	18	
46	54	21	5	26	20

I think that this average of 20 pounds can be accepted as applicable to the whole of the kelp seen since while some of the shore kelp was undoubtedly much lighter in weight the bulk was in beds similar to that at which these measurements were made, and vast beds in the neighbourhood, such as those at Nawhitti bar, must average much higher. (The plant 111 feet long measured by Mr. Lucas had a weight of the order 100 pounds.)

Two hundred and forty miles of coast line was examined. The weight of the kelp available calculated on the above estimate from the additional data shown in chart III [1] was 224,640 tons, an average of 936 tons per mile of coast line. This, it is to be observed, is much higher than that for district A, corresponding to a higher mean density of the sea-water (average value observed, 1·0225; extremes, 1·021, 1·0265).

The bulk of the kelp seen was *Nereocystis lütkeana.* Near Port McNeill, with increased salinity due to nearness to the open waters of Queen Charlotte sound, occasional small patches of *Macrocystis* occur among the *Nereocystis* beds. They become commoner farther west, and between Suquash and Hardy bay there are extensive beds of *Macrocystis.* The beds are so thick that the weight per unit area is almost certainly comparable with that for *Nereocystis,* so that the error due to a calculation on the basis of *Nereocystis* only cannot be a large one.

Before proceeding to apply the data given above to the general problems the results of the rougher examinations of the other districts will be dealt with; as no charts were made for these, some actual figures and data are included for reference for future workers.

District D (*South of District A, to Victoria*).—This was examined on July 4. Off the islands east and south of Sidney island are probably fairly large beds of kelp which would repay charting. There are a few small patches near Zero rock and Johnstone reef. The coast near Ten-mile point is surrounded by fringes of kelp, while there are numerous small beds outside Oak bay and Foul bay. The whole could be charted in two or three days, and the average is probably of the same order as that for the southern section of District A.

I saw only *Nereocystis* in this region.

District E (*Channels between the northeast of Vancouver Island and the Mainland*).—This was examined between July 18 and 21, inclusive. The route covered was from Pender harbour through Calm channel and the Caldero channels to Forward harbour, thence to Port Neville, and south through Johnstone strait and the western passage to Quathiaska cove. The greater part of this territory consists of fairly narrow channels, with very strong tidal currents. There is very little kelp throughout. There are occasional small patches and fringes, but the difficulty of collection would be great (since much of the navigation is dangerous for small boats) and the amount obtainable would not repay collection. Port Neville, opening off Johnstone strait, is almost choked up with kelp, though when I saw it at half-tide most of this bed was submerged, and invisible. The district northward from this point would repay careful examination.

Such kelp as exists in this district is invariably *Nereocystis.* The observed densities ranged from 1·014 to 1·021; in the mean, 1·019.

District F (*Barkley Sound and the Alberni Canal*).—Examined August 25 to 27. This district was selected as typical of the west coast inlets of Vancouver island. The Alberni canal is 25 miles long, very deep (up to and over 100 fathoms in many places), large quantities of fresh water flow into it, and it is quite devoid of kelp. It resembles Howe sound in general character. It opens out to Barkley sound, which is roughly

[1] Chart III should be referred to Admiralty Charts Nos. 581 and 582.

about 25 miles square, and contains numerous small islands. The shores of these are sheer for the most part, and a suitable rocky bottom for kelp growth is rare. The south side of the sound was more especially examined. There is a patch of *Macrocystis* some acres in extent inside Banfield creek, and a fringe of *Nereocystis* outside. There is a similar distribution at Dodger cove, while the neck of Useless inlet is almost filled with *Macrocystis*, and farther out are a few plants of *Nereocystis*. As far as I could judge this distribution was determined by water-movements, the *Macrocystis* growing where the tidal current was stronger. There is little other kelp worth mentioning on the south side of the sound, and no kelp in the neighbourhood of Sechart. Most of the inlets contribute fresh water and contain no kelp. The salinity of the whole sound is distinctly below ocean values, though high enough for the growth of *Macrocystis* (average density 1·0195 where *Macrocystis* was found growing). The kelp in the sound would not repay collection. I am told that there is a similar distribution in Clayoquot sound, farther north, and that in Nootka sound, still farther north, the amounts are larger. I do not think that the west coast of Vancouver island need be examined further at present.

District G (*From the north of Banks Island to Prince Rupert and Hodgson's Reefs*).—This district was only seen in small part, on dates between July 28 and August 6. Throughout this period the weather conditions were unfavourable.

White Rocks, Banks Island.—The coast line here was examined for some miles. It consists of a vast network of narrow passages between small islands and Banks island itself. These passages are all fairly well filled with kelp. In the inside passages, where the tidal currents are stronger, *Macrocystis* predominates. Outside, where there is more wave motion but less current, *Nereocystis* is present in thick fringes 25 to 50 yards wide. I was informed that there is a similar thick distribution of kelp along the west coast of Banks island and the islands to the south of it (Estevan, Aristazable, etc.). The amounts of kelp present per mile of coast-line are at least of the order found for district C, and probably higher. *Macrocystis* plants run about 30 feet in length. *Nereocystis* plants are of medium size, about 10 to 15 pounds weight.

Kitkatlah Inlet.—There are thick fringes of kelp everywhere.

Freeman Passage, Porcher Island.—On the south side of the passage there is a bed of *Nereocystis* about 2 miles by half a mile in extent. On the north side there is a smaller bed.

Spire Reef, near Prince Rupert.—There is a bed of *Nereocystis* here several acres in extent.

Metlakatla Bay.—There are two beds here, one 1 by ¾ mile, the other ¾ by ¼ mile, both consisting of medium-sized *Nereocystis* plants.

Tugwell Islands.—Thick fringes of *Nereocystis* are present, and a large bed off the northeast point.

Hodgson Reefs.—There is here a bed about a mile square, of medium-sized plants.

All the above beds are thick.

Lucy Island.—Several small patches of *Nereocystis* are present.

Qlawdzeet Anchorage, Stephen Island.—Thick fringes of kelp, about 50 yards wide, surround the whole shoreline. Both *Nereocystis* and *Macrocystis* are present.

Tree-nob Group.—The islands, as far as seen, were all surrounded by wide fringes of *Nereocystis*. The plants were not very heavy. I was informed that there was a similar thick distribution north to the Dundas islands.

District H (*the Queen Charlotte Islands*).—As previously mentioned, an attempt to examine the kelp beds off these islands was prevented by the outbreak of the war.

For the undermentioned data I am indebted to Capt. Holmes Newcomb, of the D.G.S. *Malaspina.*

Cape Naden to Bruin bay, wide fringe.

Langara island, east and south sides, thick fringe.

Frederick island to cape Knox, west coast of Graham island, a bed 15 miles long, with an average width of 1¼ mile.

Masset and Naden harbours, fringe.

Outside Masset harbour, eastwards, bed 1½ by 1 mile, small plants.

Cumshewa inlet, east coast of Graham island, a bed 7 by 2 miles on the south side of the inlet; a second 5 by ½ mile on the north side (McCoy's cove to Clew); both thick.

Farther south the greater part of the rocky coast is fringed thickly with kelp, especially in the inside channels; e.g., Burnaby channel is solidly filled by a bed 3 by ½ miles in extent.

Estimating on the above figures alone, and assuming thick beds of *Nereocystis* with an average weight of 15 pounds per plant, the available kelp from the Queen Charlotte islands would amount to more than a million tons. An accurate survey of these beds is therefore very desirable. The waters are treacherous, and such a survey would require the assistance of a man thoroughly familiar with the coast.

TOTAL AVAILABLE KELP AND ITS VALUE.

From the data given above it is possible to get some idea of the total value of the Pacific Coast kelp beds, but at present the calculations must be based partly on analyses made of samples obtained farther south in the Puget Sound region. I have obtained samples for analysis at various points along the British Columbia coast; these have been forwarded to Dr. Shutt at Ottawa. His results, when available, can be used to correct the following figures. I do not anticipate that much variation of composition will be found.

I have determined the water-content of *Nereocystis* at Departure bay, with the following results:—

Part of plant taken.	Percentage water content.	Dry residue.
	per cent.	per cent.
Fronds	91·91	8·09
Pneumatocyst	93·94	6·06
Stipe	87·29	12·71
Holdfast	87·17	12·83

Since an examination of the figures for plant-weight reveals a weight-ratio of frond to pneumatocyst and stipe (available portion) of between 3 and 4 to 1, if the figure 8 per cent be taken for the dry weight it will certainly give a conservative estimate.

Turrentine's figures for the potassium chloride and iodine contents of *Nereocystis* obtained in Puget sound are on the average 30·9 per cent potassium chloride and 0·14 per cent iodine.[1] My own figures for iodine in *Nereocystis* from Departure bay average 0·12 per cent iodine.[2] These are all expressed for the dried plant. In the following calculations I have assumed 30 per cent potassium chloride and 0·12 per cent iodine. (Since *Macrocystis* contains similar amounts of potassium chloride

[1] "Fertilizer Resources of the United States", Senate Document 190, 1912, p. 220.
[2] Cameron, *J. Biol. Chem.*, vol. 18, p. 350, 1914.

and iodine, no marked error will be made by calculating throughout for *Nereocystis* plants.) The potassium chloride values are calculated on the American quotations for the crude salt before the outbreak of the war ($39.07 per ton on an 80 per cent basis; hence reckoned as $50 per ton potassium chloride). Since there is no duty on this salt into Canada, these figures can be applied here. The iodine values are calculated from the values quoted for Canadian imports in 1913 ($1.73 per pound, equalling $3,875 per ton).

—	District A 500 miles.	District B 200 miles.	District C 240 miles.
	tons.		tons.
Total kelp available	122,760	....	224,640
Dry weight	9,820	....	17,970
Weight of potassium chloride contained	2,946	....	5,391
Weight of iodine contained	11·78	....	21·56
	$		$
Value of potassium chloride contained	147,300	....	269,550
Value of iodine contained	45,647	....	83,545
Total value	192,947	....	353,095

Since these three districts may be held to represent fairly accurately and equally the distribution of kelp over the whole coast, an average of the results can be applied to the whole coast line, which is commonly estimated as 25,000 miles.[3]

—	District A.	District B.	District C.	Mean.
	tons.	tons.	tons.	tons.
Average weight of potassium chloride per mile	5·9	....	22·5	9·4
Average weight of iodine per mile	0·024	....	0·09	0·038

Hence, total annual yield of potassium chloride is equal to 235,000 tons worth (valued at $50 per ton), $11,750,000.

Total annual yield of iodine is equal to 950 tons worth (valued at $3,875 per ton), $3,680,000.

The total calculated value is, therefore, over fifteen million dollars annually. It must be remembered that at present and during the present war the price of potassium chloride will remain much higher than that quoted, but that under normal conditions the marketing of large quantities of potassium salts (or of iodine) would probably result in a considerable lowering of price by the controllers of the present supplies.

It is perhaps doubtful whether under normal conditions the kelp in districts *A* and *D* could be harvested at a profit. The territory extending from the north coast of Vancouver island to the Dundas islands, including the islands in Queen Charlotte sound and the other islands Aristazable, Estevan, Banks, Porcher, Stephen, the Tree Nob group, etc., has much more extensive beds, and as far as I can judge the figures obtained for district *C* are applicable to the estimated coast-line comprised in this territory, but much of it has not yet been charted. From the available charts it would appear to be at least 2,000 miles in length, while 3,000 miles is not improbably a more correct figure. Using the smaller figure, with the data from district *C* (22·48 tons of potassium chloride and 0·09 ton of iodine per mile), the total available yield should be 44,960 tons potassium chloride and 180 tons iodine, worth, respectively, $2,250,000 and $700,000, a total of $2,950,000 for the annual harvest.

[3] See for example C. McLean Fraser, *Trans. B. C. Acad. of Science*, vol. 1, p. 49.

It would seem almost certain that the kelp in this district could be obtained and harvested at a profit. It would at present more than supply Canada's needs for potassium salts and iodine.

The annual value of the beds off the Queen Charlotte islands is also more than a million dollars at pre-war rates. The difficulties of harvesting will be greater.

RECOMMENDATIONS.

I submit the following recommendations:—

(1) The charting of the kelp beds from the north of Vancouver island to the Dundas islands should be completed. This can be carried out properly only between July and September of any year, when the kelp is thickest and the weather conditions are most favourable. The waters are dangerous for navigation in many parts of this territory. A seaworthy steamer carrying a small power launch, and the services of an efficient navigator with some knowledge of these waters are essential. The work would occupy at least two seasons. Much of the coast has not been charted, and it would be necessary to prepare a rough chart, which could be done in the two months previous to the actual kelp survey.

(2) The kelp beds of the Queen Charlotte islands should be surveyed. This must be carried out at the same period of the year. The difficulties of navigation are greater, from the dangerous nature of the waters.

(3) Further information should be obtained concerning the best period for cutting the kelp. It must not be cut too early or the discharge of the spores may be affected and next year's crop lessened. It will be necessary to make careful observations of definite areas over a series of years to find out whether the time of cutting affects the succeeding growth harmfully. If cutting is delayed too long, the fronds will have commenced to decay, and the total yield may be considerably diminished. This will not matter initially, when only part of the kelp beds is being utilized, and especially for works conducted on an experimental basis, so that until definite information is available, permission to cut kelp should probably be granted only between August and December, inclusive.

(4) There is not enough kelp to allow private companies to utilize the same beds. The areas will require division, and for effective working a particular area will have to be allocated to a single corporation. Policing will be essential, to prevent too early cutting. Perhaps this could be undertaken by the fishery officials.

(5) It has been stated by various investigators that the removal of kelp may interfere with the food supply of certain fishes, and may increase the dangers of navigation by removing natural breakwaters; further, that the presence of kelp in waters not well charted is of considerable assistance in the navigation of boats of light draught. The latter points may be important, and further consideration of them is required. Any difficulties can probably be overcome by more accurate charting of the coasts and increased buoying of the reefs.

(6) It will be necessary to secure information as to the best methods of harvesting the kelp, and obtaining from it the potassium chloride and iodine. American experiences are available,[1] and the conditions of labour and transport in British Columbia are probably not markedly different.

---

[1] The technology of the seaweed industry is summarized in the Congress Report, No. 190, already frequently referred to, on pages 232 to 262. Some idea of the kind of manufacturing plant required and the cost of operation may be gathered from the following quotations:—

(*a*) W. C. Phalen, "Potash Salts, Summary for 1913," from "Mineral Resources of the United States, Calendar Year 1913—Part II", Washington, 1914: (pp. 94-6):—

"Commercial Utilization of Kelp.—Since interest has been aroused in kelp as a source of potash salts, several companies have been formed having in view its commercial exploitation, either in the dried form as a fertilizer or for the potash salts and the other valuable ingredients, such as iodine, which it contains. The names of eleven companies formed ostensibly to engage in the kelp industry have been brought to the attention of the survey during the last year. In

(7) No company or individual should be given permanent or unrestricted rights to remove and utilize kelp in British Columbia waters until the information outlined has been obtained.

(8) The desirability of establishing a Dominion experimental plant in the northern or central part of the British Columbia coast to carry out further experiments as to the best method of obtaining the commercial products should be considered.

---

geographical distribution, these companies are located in the vicinity of Puget sound with headquarters chiefly at Seattle, and on the southern California coast near Long Beach, Los Angeles, and San Diego. Two of these companies were mentioned in this report for 1912.

"The American Potash Co., with offices at Los Angeles, Cal., plans to utilize the kelp in the vicinity of Long Beach. This company was formed by the merging of two other companies, one of which was the Coronado Chemical Company, of San Diego and Cardiff. It is stated that work will begin early in 1914 on the manufacture of potash and other by-products from kelp at a plant to be built at Long Beach. The plant is to be erected on the unit system, and construction work on it began early in 1913. The work of manufacturing potash will begin on the completion of the new buildings that are expected to be finished about April 1, 1914.

"The Pacific Products Co., of San Pedro, Cal., with a capital of $100,000, is reported to have a factory site on the California coast opposite the kelp grove outside of Point Fermin.

"The Pacific Products Co., of Seattle, Wash., capitalized at $125,000, will build a factory for the manufacture of fertilizer materials and by-products from fish and kelp at Port Townsend, Wash. Several beds of kelp have been optioned at the head of Puget sound, where a large quantity of seaweed will be harvested each year and transferred to the factory at Port Townsend. This company will also make a business of obtaining dogfish, and of utilizing the offal from the fish canneries in the vicinity. The first unit of the plant for converting kelp and dogfish into fertilizer material was reported completed in July 1913.

"The Pacific Kelp Mulch Co., is located at Terminal island, 1 mile east of East San Pedro, on the San Pedro, Los Angeles and Salt Lake railroad. The company has been gathering kelp from the ocean during the last two years and disposing of it to the farmers and fruit growers as a fertilizer. The company has developed a machine which harvests the kelp rapidly and on a large scale. The kelp is cut from 4 to 6 feet under water, and care is taken not to disturb the roots of the growing plants. It is loaded on a barge and brought to the boat landing of the plant. Here it is pitch-forked from the barge on a belt conveyor which conveys it to the cutter, being subjected during the passage to a steaming process which is practically instantaneous and which, it is asserted, removes all the adhering common salt ($NaCl$) but none of the potash salts. The cutter chops it into pieces 6 to 8 inches long—that is, of a length to be conveniently handled with a manure fork or to be harrowed under the soil after being spread. From the cutter the kelp falls into wagons or to the floor. It is then carted to the railroad and dumped into freight cars and shipped to the centres of consumption. This company has the distinction of being the first to harvest and market kelp on a commercial scale.

"The material is said to have many advantages as a fertilizer, and these are explained in a small pamphlet which has been issued by the company.

"The other companies whose names have come to the Survey as proposing to engage in the production of kelp on a commercial scale are the following: Ocean Products Co., Seattle, Wash., North Pacific Kelp Potash Co., Seattle, Wash., Pacific Coast Potash Co., Seattle, Wash., Puget Sound Kelp Potash Co., Seattle, Wash., Aquatic Products Co., Seattle, Wash., Kelp Products Co., San Francisco, Cal., Mexican Kelp Fertilizer Co., Los Angeles, Cal.

"The Survey has no first-hand knowledge of the activities of these companies".

(*b*) Note in *Pacific Fisherman*, May, 1914, p. 36:—

"American Potash, Inc., of Long Beach, Cal., which takes the kelp as it grows along the rock near Point Fermin and converts it into a fine grade of potash, together with many other by-products, is constantly enlarging its plant, and, it is said, has withdrawn its stock from the market. The plant was shut down for a short time during the latter part of April for the purpose of installing a new drier, which consists of an immense endless belt of wovenwire which runs over a hot blast, and also gets a large amount of heat from steam pipes located over the top. The dried kelp is burned and then reduced to its merchantable forms through a process of precipitation."

(*c*) Note in the Seattle *Post-Intelligencer*, August 23, 1914:—

"Congress will be asked by the Department of Agriculture to appropriate for the immediate construction of an experimental plant on Puget sound to demonstrate the commercial possibilities in manufacturing potash from kelp.

"The Bureau of Soils which has just concluded an exhaustive study of the kelp beds of the Pacific from Mexico to Alaska, in a report now being printed, strongly urges the development of the industry, and asserts that the product could be turned out in commercial quantities in from four to six months."

It should be noted, finally, that in this report I have not considered the possible preparation of phosphates or other substances from kelp. Some of these are indicated in the Congress Report, 1912, p. 249, etc.

SUMMARY.

The kelp beds of the British Columbia waters can supply far more potash and iodine than the amounts used at present in Canada. Large quantities could probably be marketed at a profit at pre-war rates. Should the present war be of long duration, all Canadian requirements can be met from this source. In any event, the industry, carried on on a moderate scale, would almost certainly be lucrative.

Definite evidence is adduced that the growth of kelp is largely dependent on the salinity of the containing water. *Macrocystis pyrifera* requires a more saline habitat than *Nereocystis lütkeana*. Both species grow more luxuriantly the more saline the containing water.

CHARTS ILLUSTRATIVE OF THE REPORT.

Chart I. A general outline of the British Columbia coast, showing areas charted (thick lines) and areas examined but not charted (dotted lines).

Chart II.—Detailed map of kelp area A, from the international line, Juan de Fuca straits, to Ballenas island, near Nanoose bay.

Chart III.—Detailed map of kelp area C, in Queen Charlotte sound.

(This report received for publication October, 1914.)—E. E. P.

Ballenas Is.
Howe Sound
STRAIT OF GEORGIA
CHART No. II
PROFESSOR CAMERON'S KELP REPORT
EXPLANATION OF CHART
Thick fringe
Less than 50 yards wide; thin.
wider than 100 yards, the width in yards is shown on the chart).

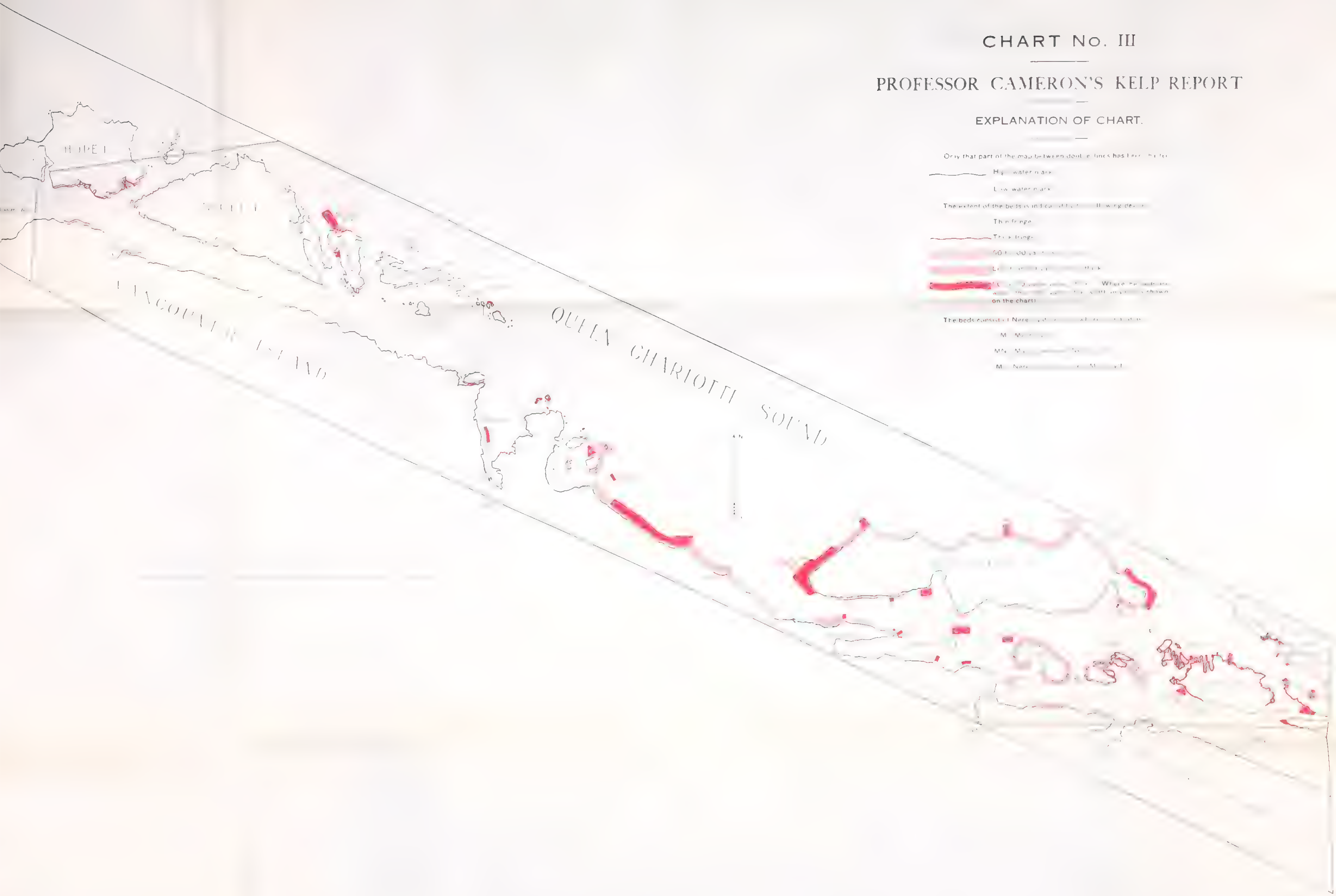


CHART No. III
PROFESSOR CAMERON'S KELP REPORT
EXPLANATION OF CHART.
Thin fringe
Thick fringe
on the chart)
QUEEN CHARLOTTE SOUND
VANCOUVER ISLAND

Long Beach Pond at high tide. Viewed from a hill at the northeast end.

IV.

LOBSTER SANCTUARIES AND HATCHING PONDS: AN INVESTIGATION OF THE LONG BEACH LOBSTER POND, DIGBY COUNTY, NOVA SCOTIA, IN 1914.

By Professor A. P. Knight, M.A., M.D., F.R.S.C., etc.,

Professor of Animal Biology, Queen's University, Kingston.

(With six plates).

ACKNOWLEDGMENTS.

Acknowledgment is due to the Department of Naval Service, Fisheries Branch, for placing all the berried lobsters in the pond at the disposal of the scientific staff. Without these it would have been impossible to carry on the investigation.

Acknowledgment is due also to Professor Prince, the chairman of the board, for furnishing important references to the literature of the subject. In fact, it was he and Professor Macallum, the secretary of the board, who suggested the investigation.

SCIENTIFIC STAFF AT THE POND.

A. P. Knight, M.A., M.D., Professor of Physiology, Queen's University.
H. G. Perry, M.A., Professor of Biology, Acadia University.
W. E. Sullivan, Ph.D., Professor of Anatomy, University of Milwaukee.
A. B. Dawson, Acadia University.
W. Arnold Mersereau, University of New Brunswick.

RESULTS OF THE INVESTIGATION.

The following summary of the results of the investigation and of the conclusions reached will indicate the lines of the research.

In considering whether a rearing plant should be permanently located at Long Beach, certain very obvious disadvantages must be squarely faced:—

(1) The place is not easily accessible, consequently transportation and freight charges are excessive.

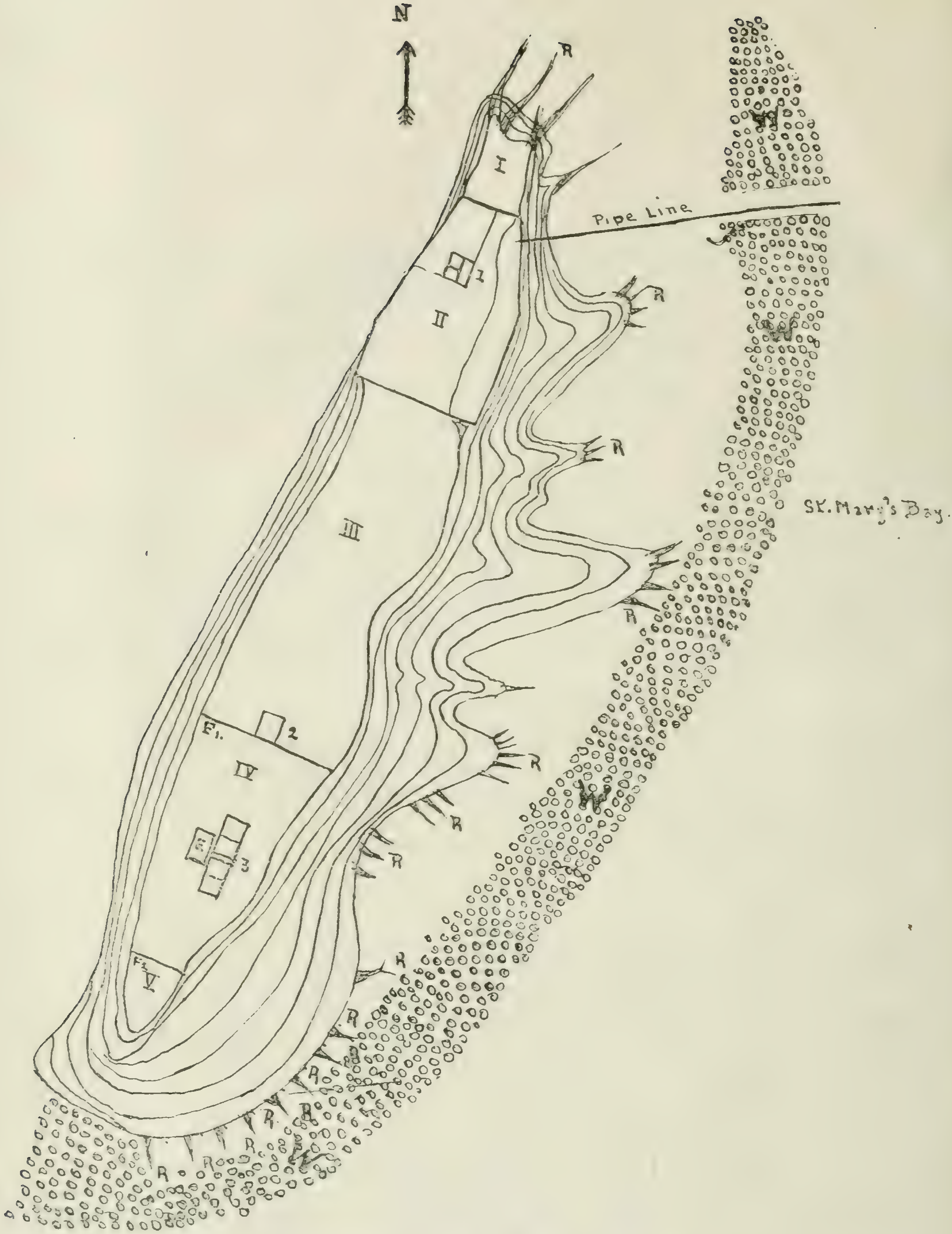
(2) The water is too cold and, therefore, delays the development and moulting of the larvæ.

(3) There is not nearly depth enough of water even under the present number of hatching boxes, there being only 18 to 20 inches under our four boxes at low tide, whereas there should be at least 6 feet. If the full complement of boxes (24) are to be installed, an area of 400 feet by 60 feet by 10 feet depth would have to be provided.

(4) Too great a growth of moulds, diatoms, and Cyanophyceæ, causing pollution of the water and sickness and death among the larvæ.

(5) Too much cloudy and foggy weather, thus depriving first stage larvæ of the sunshine into which they naturally swim whenever they can.

As against these disadvantages may be placed two very important advantages, namely, placidity of surface and suitable salinity. The surface of the pond is protected from high winds throughout its length by a hill on the west side and the high sea wall on the east. According to Mr. Martin, who investigated the subject last season, the salinity nearly equals that of the bay of Fundy. The amount of fresh



GENERAL PLAN OF THE PONDS.

W, W, W, W. Stone or sea-wall separating the pond from St. Marys bay on the east.

R, R, R, R, etc. Points inside of the sea-wall, at which rivulets enter and leave the pond during the rise and fall of the tide. The numerous wavy lines are intended to represent different levels of the water between high and low tide.

I, II, III, IV, V, indicate the five sub-divisions of the pond from the north to the south end.

Sub-division II, the cement pound, is an elongated six-sided enclosure, further subdivided into three smaller compartments, each 20 feet by 20 feet, as at 1, and one large compartment, 85 feet by 85 feet.

The wooden enclosure, marked 2, in sub-division III, is a temporary structure, 20 feet by 20 feet, and accommodated about 200 berried lobsters in 1913, when the cement pound was being built.

The hatching and rearing plant, 3, is located in sub-division IV, between fence F1 and F2. The letter E represents the position of the engine house. The four squares east of the engine house represent the location of the four hatching and rearing boxes. (Drawn by A. B. Klugh, M.A.)

water entering from the hillside is insignificant, and in my judgment would in no way endanger the life or undermine the vitality of any adult lobsters confined in the pond.

Notwithstanding the great disadvantages, it is only fair that the plant should be operated another season before a final judgment can be rendered as to the suitability of the pond for rearing young lobsters to the fourth or fifth stage. The disadvantages, however, overbalance the advantages so much that in my opinion the board would not be justified in asking the Government to expend any money upon the cement pond, excepting a small sum sufficient to provide the adult lobsters with shelters from the excessive light and heat of the sun, and perhaps a further small sum in reducing the leakage.

(6) While Long Beach pond is not likely to prove suitable as a reserve in which lobster larvæ can be raised to the lobsterling stage, it may nevertheless become even more valuable to the lobster industry: (1) as a sanctuary for berried females during the open season, and (2) as a mating ground for male and female commercial lobsters after the open season has ended.

LOCATION.

Long Beach pond is an elongated area of about 5 acres of sea-water at low tide and 7 acres at high tide. It is situated 4 miles from the southwest end of Digby Neck, Digby county, Nova Scotia.

The sea-wall which separates the pond from St. Mary's bay on the east is nearly 2,500 feet long, and varies in width from 20 to 50 feet on top. It consists of boulders of all sizes up to about 100 pounds intermixed throughout with sand and gravel. As a consequence, sea-water enters and leaves the pond along nearly the whole length of the sea-wall, but especially at points marked R.R.R., etc., on the general plan.

TIDES.

The tide rises and falls in the pond between 5 and 6 feet at the lower or southwest end, less, of course, at the upper or northeast end, and is later than the rise and fall in St. Mary's bay by about two hours. This delay in rise and fall is due to the obstruction which the sea-wall offers to the ingress and egress of the sea-water.

For convenience of description the pond may be considered as consisting of the five subdivisions, marked on the general plan as I, II, III, IV, and V.

Division I is the shallowest part of the pond, consisting of a small pool of no importance at the northeast end.

Division II is in some respects the most important portion of the pond. It is known as the cement pound, being inclosed on all sides by cement walls. It was constructed by the Department of Marine and Fisheries for the purpose of impounding berried lobsters, or holding them during the open season, the intention being to liberate them again at the beginning of the close season so that they might hatch their eggs naturally in the sea.

Division III, like Division II is very shallow at low tide, varying in depth from an inch or two to 8 or 10 inches in most places, but much of it is a mud-flat covered with sea-moss (Chætomorpha).

Division IV, between the wooden fences (E. 1 and F. 2), is the deepest of the pond. Here, over an area of about 25 feet by 50 feet, the water is about 5½ feet deep at low tide.

Division V is the part at which there enters and leaves probably two-thirds of all the water which composes the tidal volume into and out of the pond.

Long Beach pond is not directly accessible by railroad, boat, or stage. As a consequence, the cost of freighting construction material and all kinds of supplies to the place is greatly in excess of what it would be, if a more accessible location had been

chosen. For example, it cost nearly $5 per 1,000 feet b.m. to bring lumber from Weymouth, 7 miles away, and lay it down on the beach where construction was going on. Then, too, the cost of labour is high. Labourers ask $2 a day, handymen $2.25, carpenters $3 and $3.50 a day, a master carpenter $4. The rate for an ox-team and man ranges from $4 a day to $3. These wages may not be too high; but, at any rate, they exceed the rates which prevail around Little River.

THE PONDS AND SANCTUARY.

The acquisition of Long Beach pond, Nova Scotia, and Gabarus pond, Cape Breton, by the Government as sanctuaries for buried lobsters should need no defence. In fact "the reservation of natural inshore lagoons, harbours and coves" as breeding grounds for lobsters was recommended by the Lobster Commission of 1898 (see page 33 of their report).

It is not necessary that the sanctuaries should all be like the two mentioned above. On the contrary, they should be of different sizes, depending upon the varying needs of different localities. Some of them might well be very small harbours, having narrow entrances, and sheltered from high winds. Such entrances could be closed with a latticed fence or gate so as to admit tidal water freely, and at the same time retain lobsters. Others might be small wooden inclosures placed in coves or other sheltered places along the coast. Small sanctuaries might be quite as useful as large ones, and would not cost one tithe of the money.

To realize how useful a small wooden sanctuary may be, one has only to learn that the wooden pounds (within Long Beach pond) which accommodated 196 berried lobsters in 1913, during the time that the cement pound was being built, was a structure only 20 feet by 20 feet. "Too small," you exclaim. Of course it was; but it was sufficient to retain the lobsters until the open season ended when they were returned to the sea to hatch their eggs in the natural way.

This wooden enclosure could not have cost more than $150; it might just as well have been located in any other sheltered place than in Long Beach pond, and it accommodated nearly 200 berried lobsters throughout the open season of 1913 and through part of the season of 1914.

It must not be understood that this report advocates the establishment of tidal enclosures without any regard to cost. On the contrary, it recommends that a number of small wooden enclosures, costing not more than $200 or $300 each, be established as an experiment along the maritime coast at points convenient to large lobster factories, and it bases this recommendation upon the work accomplished at Long Beach pond in 1913 and 1914.

In making this recommendation it must be distinctly understood that the berried lobsters are not to be retained in the pound while hatching their eggs. They should be returned to the open sea as soon as the eggs show the first signs of hatching out. Our observations at Long Beach are decidedly opposed to the idea that the lobster larvæ could ever grow into adults or even "tinkers" within the confines of the pond. There were too many enemies present in the pond to permit of the growth of even a single larva into an adult lobster.

Furthermore, this recommendation is based upon the supposition that berried lobsters collected by the patrol boats shall be properly cared for during transportation. They should be towed to the sanctuaries in specially constructed tanks, or they should be packed in moist sea-weed and kept cool with ice throughout the journey.

Then again on reaching the sanctuaries the mother lobsters should get all the food they will eat—and good food, not gurry. Of course every one knows that the average fisherman feeds his impounded lobsters (if he feeds them at all) upon the decaying heads, backbone, ribs, fins, and viscera of fish which he is cutting up for

bait; and he will tell you with supreme confidence that lobsters are fond of the disgusting mess. To be sure, starving lobsters will eat bones, just as starving men have been known to eat their boots; but to assert that putrefying gurry is all the food that berried lobsters require is to assert what cannot possibly be true.

Another necessity in conserving the health and strength of the animals is shade. In their natural haunts they shrink from the light, hide under rocks or in weeds, and burrow in the mud. Why cannot these natural habits of the animal be recognized in any sanctuary that may be provided for them? Shelters in the shape of boxes made of cement or wood should be provided on all areas in which they are confined. If the space is small a dark canvass "fly" such as is stretched over a tent in hot weather would meet the habit of the animal to some extent at least. Surely if it is worth while to impound lobsters at all for breeding purposes, it is worth while to see that animals are well cared for both during transportation and confinement. The attitude of the intelligent stock-breeder towards his breeding animals is the attitude which should be inculcated upon fishermen in regard to berried lobsters.

Lastly, before a decision is reached as to the location of any inclosure, the pond, cove, or harbour in which it is proposed to locate it, should be subjected to a biological examination. Its fauna and flora should be determined for the purpose of discovering possible enemies of both adults and larvæ. Its bottom, its depth of water at high and at low tide, its available food supply for lobsters, its landing facilities, its accessibility for securing supplies—all of these things must be carefully considered if success is to follow the inauguration of any government scheme of tidal enclosures.

DECREASE OF LOBSTERS.

Failing adequate means of protection, it looks to-day as if the future plenitude of the lobster were doubtful. The catch in proportion to the men and gear employed in it has been steadily falling off in recent years. The canneries have been accepting thousands of "tinkers" or half-grown lobsters, and as long as the canners will buy, the fishermen will continue to catch and sell these immature animals, thus cutting off the supply of full-grown lobsters at its very source. It is, of course, illegal to sell or buy female lobsters with eggs on them; but it is an easy matter for the fishermen to scrape off the eggs. In proportion, therefore, as "tinker" lobsters are destroyed and eggs are removed from the mother animals, in just that proportion will the supply of lobsters be cut off in the future.

As against this wastage of lobster life the close season counts for something and so do the hatcheries, though there is some doubt about this. As a means of replenishing our depleted lobster waters, the hatcheries have been long known to be unsatisfactory. Moreover, the expense of running them is great. The mother lobster can hatch out a higher percentage of eggs than any artificial hatchery can, and she can in addition, distribute the young in the sea more widely, more uniformly, and more safely than any employee of a hatchery.

Why not, therefore, give the mother lobsters a little chance? Let the Government extend the lobster pond system, and establish a number of sanctuaries; let the fishermen be paid the same price for "berried" lobsters delivered at the sanctuaries as for male adults delivered at the canneries; let these mother lobsters remain in the ponds or sanctuaries during the open season and, when the close season begins, let them be returned to the sea to hatch out their eggs in their natural way, and it may fairly be claimed that the Government is at least taking one more efficient step towards the protection of the lobster industry.

THE CEMENT POUND.

A 5 acre sanctuary—the area at Long Beach—is, however, a pretty large area over which to allow lobsters to roam if they are to be fed regularly, kept under proper observation, and if it is desired to recapture and transport them to some other area

at a later date in the summer. Supervision and caretaking over a large area must be limited in some way, or the expense of running the pond would be very great. Consequently the department came to the conclusion that the northeast part of the pond should be inclosed by cement walls, making what may be called a cement pound within the natural pond. [See subdivision II of the general plan of the pond.]

To ensure that animals confined in it should have an adequate supply of fresh sea-water, the pound was connected with St. Mary's bay by an earthenware pipe 20 inches in diameter. When the tide outside rose higher than the bottom of the pound, a valve opened automatically, and it was expected that a large volume of sea-water would be retained in the pound. The scheme looked feasible, but the cement pound as it existed in the summer of 1914 was quite useless, because it would not retain water as planned.[1]

OTHER USES FOR THE POUND.

Three other uses have been suggested for the cement pound besides that of affording protection for berried lobsters. One of these was that the Biological Board should use it for the purpose of rearing lobster larvæ to the lobstering stage, that is, to the stage at which young lobsters cease to live at the surface of the water and descend to the bottom.

In accordance with this suggestion the writer spent three days at the pond about the middle of May, and reported to the board that while no use could be made of the cement pound for the purpose suggested, on account of the insufficiency of the water, even at high tide, he thought a small experimental rearing plant of the Wickford type could be located at the opposite or southwest end.

Even there the writer was in doubt as to whether there was a sufficient depth of water at low tide. He found the depth to be not more than 5½ feet. The rearing boxes which it was proposed to use would be 4 feet deep and would be immersed about 3½ feet in the water so that there would be less than 2 feet below the boxes, where 6 feet at least would be regarded as a minimum. Thus, before the experiment was undertaken at all, the insufficiency of the depth of water and area of water in the pond was pointed out. Moreover, this limited area of 25 feet by 75 feet would admit of the installation of only four hatching boxes, whereas the full complement of boxes in the Wickford system contemplates as many as twenty-four boxes. In order, therefore, to have an area of sufficiently deep water anywhere in the pond, to justify the installation of a complete rearing plant, it would be necessary to dredge an average of about 7 feet from the bottom of the pond over an area of approximately 400 feet by 60 feet. Either this, or a deep canal would have to be cut in the sea-wall, and enough water admitted from St. Marys bay to flood the pond 6 feet deep at low water. Which of the two plans would be the more economical is a question which only an expert hydraulic engineer could decide, but neither plan should be adopted until our present plant has been run for another season at least.

THE WICKFORD PLAN OF REARING YOUNG LOBSTERS.

The Wickford plan of rearing lobsters was the result of eight or ten years' of experimentation by Professor A. D. Mead and his assistants working under the auspices of the Rhode Island Fish Commission. Up to 1898 nearly all efforts to increase the lobster supply artificially were limited to hatching lobster eggs in jars.

Now, lobster hatching must be clearly distinguished from lobster rearing. Just as the hatching of chickens is a different process from the rearing of chickens, so the hatching of lobsters is quite a different matter from the rearing of lobsters. The

[1] Since this report was written, the Deputy Minister of Naval Affairs informs me that the leakage of water from the pound has been stopped, and that the mud and slime on the bottom have been removed under the direction of a Government engineer.

former process has been carried on in our Dominion hatcheries since 1891. Hitherto our hatcheries have confined their efforts to scraping the eggs from the abdomen of the mother lobster, placing them in jars of well aerated sea water and, when the young have come out of their "shells," emptying them into the sea. Many millions of young lobsters have been hatched in this manner every year since 1891.

The rearing of lobster babies for three or four weeks before putting them into the sea is the main feature of the Wickford system. In this system the mother lobsters do the hatching just as naturally as they hatch the young in the sea. The only difference is that in the Wickford plant the mother or berried lobsters are placed in large hatching boxes 10 feet long by 10 feet wide and 4 feet deep, set down in the sea about 3½ feet. The water in these boxes is kept aerated by revolving paddles. The animals are shaded by canvas covers, and regularly fed. You may call these boxes the "nests" of the mother lobsters if you like. At any rate they serve the same purpose as nests do in the rearing of young birds.

Every evening, especially if the weather is fine and the eggs ready to hatch, the mother lobster may be seen moving to and fro those parts of her body to which the eggs are attached, and presently a considerable number of the young escape from their "shells" and swim about near the surface.

These young are removed from the hatching box to other boxes called rearing boxes of the same size but with different length of paddles revolving in them. The "babies" are dipped up with shallow dip-nets made of cheese cloth, and are usually counted with the aid of an automatic counter. As many as 25,000 may be put into a rearing box; but at Long Beach we never transferred more than 15,000, and generally only 5,000 to 8,000, as we were anxious to rear quality rather than numbers during our first season.

With the transfer of the young, or larvæ as they will often be called, to the rearing boxes, the real work of rearing young lobsters begins. Feeding the larvæ is perhaps the easiest part of all. At Wickford they are fed chiefly upon hens' eggs, scrambled and pulverized; but clams and fish finely shredded are equally good.

Three big difficulties confront the operator: (1) the aeration of the water in the rearing boxes; (2) the prevention of cannibalism among the larvæ; and (3) the spread of infectious disease.

The aeration of water in the boxes in which lobsters, young or old, are kept is just as necessary as fresh air is for human beings or for domesticated animals. In fact, the aeration of water for aquatic animals corresponds precisely to ventilation for terrestrial ones; for, just as fresh air must be admitted to our houses, and frowsy air allowed to escape, so the stale sea-water in the hatching and rearing boxes must be replaced by fresh sea water if the lobsters are not to be smothered for lack of oxygen. The mechanism by which aeration is brought about will be described later on.

As to cannibalism, it is generally recognized that the younger and weaker larvæ are subject to danger from the stronger and more active ones. The more the larvæ are crowded together, as they must necessarily be in rearing boxes, the greater the extent to which the habit is likely to grow. Lack of food must tend to promote such a habit, as one can readily understand. If, however, the larvæ are kept moving about rapidly in the water of the rearing boxes, they are to some extent kept separate from each other and thus the danger of cannibalism would be greatly reduced. Aëration of water and reduction in cannibalism would be both controlled, to a very considerable extent at least, by the rate at which the water circulates in the boxes.

Perhaps the greatest difficulty of all is the prevention of disease. Just as human beings are killed by infectious diseases like measles, scarlet fever, diphtheria, small-pox, and consumption, so our first batch of 40,000, as well as our second batch of 30,000, were nearly all attacked and killed by infectious diseases caused by very tiny plants. Three of these plants are known as diatoms, and the fourth as a fungus.

The young of nearly all animals are more liable to such diseases than the adults. In Canada about thirteen babies die during the first year out of every 100 that are born; but nevertheless about three babies out of every four grow into men or women. In the case of lobster babies, however, only one out of every 15,000 grows into an adult. The inexorable forces of nature in the shape of cold, famine, and disease kill off the young by millions.

Whence came the parasitic plants from the growth of which our larvæ died? The answer to this question lies at the very root of our failure to rear larvæ. Did they come from the pond water, or did they come from the mother lobsters? A physician when looking for the origin of a case of scarlet fever would first ask whether any other member of the family had previously suffered from the disease. If not, he would look for some point of contact between the patient and some outsider who had been previously ill with the disease. Similarly, the staff at Long Beach cast about for the possible source of infection. Very early in our first experiment the microscope revealed the principal diatom adhering to the limbs of the larvæ. Later on, its growth on the limbs became so thick and "fuzzy" that any one could recognize it with the naked eye, once it had been pointed out.

Where did it come from? Search (under the microscope) among scrapings taken from the legs and "feelers" of mother lobsters showed the presence of the four kinds of parasitic plants. Here, then, was one possible source of infection. In hatching out their eggs, the mother lobsters may have transferred the parasites to their young, just as a human mother may give an infectious disease to her child.

The other sources of infection were, of course, the sea or the pond water. In order to determine whether the parasitic plants come from the pond water, or from the sea, tow-netting was carried on: (*a*) in St. Marys bay, and (*b*) in one of the hatching boxes which had been raised, cleaned, and repainted. The examination of the material obtained in this way, as well as the descriptions of the structure of the diatoms and fungus, awaits the examination by experts to whom the material has been sent, and who will report upon it in the near future.

In one particular the parasitic plants which caused the death of the larvæ are quite unlike those which cause infectious diseases among human beings. The former rapidly increase in number when growing in the light, the latter are usually killed off by the light. To keep diatoms, therefore, and other parasitic plants off mother lobsters, they should be kept either in deep water into which comparatively little light can penetrate, or they should be provided with artificial shelters from the light. Sheltering from sunlight would not merely be conforming to the natural habit of the animal, but it would be a means of lessening the parasitic growths upon them, and therefore preventing the spread of growths to their young.

An observation made by Williamson would appear to explain how parasites might grow profusely on berried lobsters between the time they reached the pond and the time they hatched out their young in our hatching car:—

> "In each of the two large concrete tanks were placed two female lobsters. In one tank a board shelf afforded protection from the sun so that only the antennæ of the lobsters were exposed to its rays. In the other tank there was no protection from the sun whatever. In the first case, after the summer season was over the lobsters themselves were free from growths of all sorts, but the antennæ were covered. The bodies and appendages of the lobsters which were confined in the exposed tank were, however, quite hidden by the prolific growth of sea-weeds, laminaria, young mussels, etc."—(*Quoted from the Report R. I. Com., 207th Jan. Sess., 1906, foot-note to sec. xvi, 'Influence of Parasites.'*")

A clear distinction must be made between the effect of diatoms on larvæ and the effect of a fungus growth. The former act mechanically and by clogging the limbs

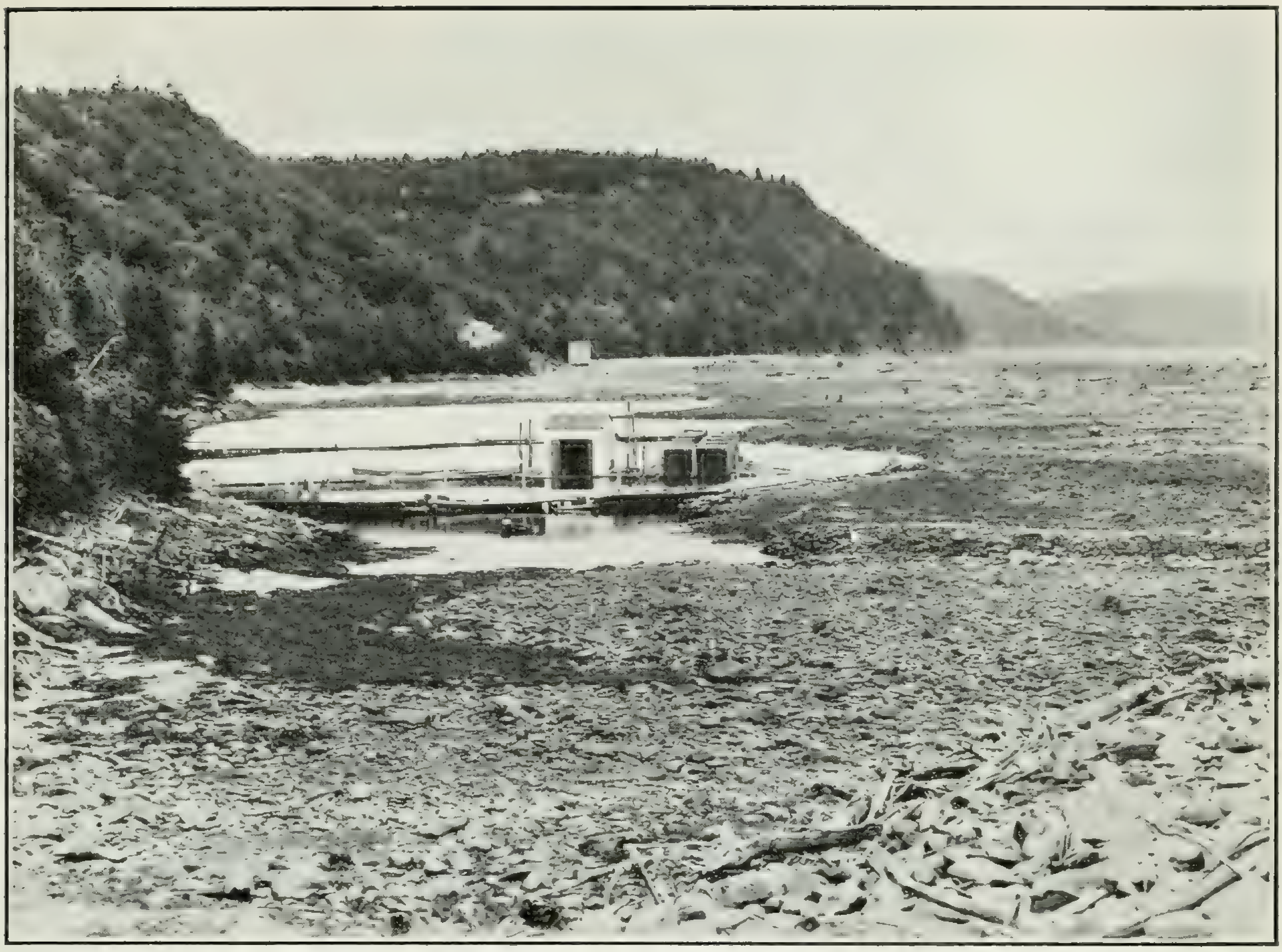


Fig. 1.—The pond as seen from the southwest at low water. Our hatching plant is in the foreground. A wooden fence, F2, is seen in the foreground, and one, F1, farther back. These two fences form the boundaries of sub-division IV. Sub-division V. is in the foreground.

Fig. 2.—The pond at high water viewed from an upper window of the mess-house. The cement pound is seen in the foreground. Wooden partitions at the right hand subdivide the pound into three small compartments and one large one. The rearing plant may be seen at the farthest end of the pond.

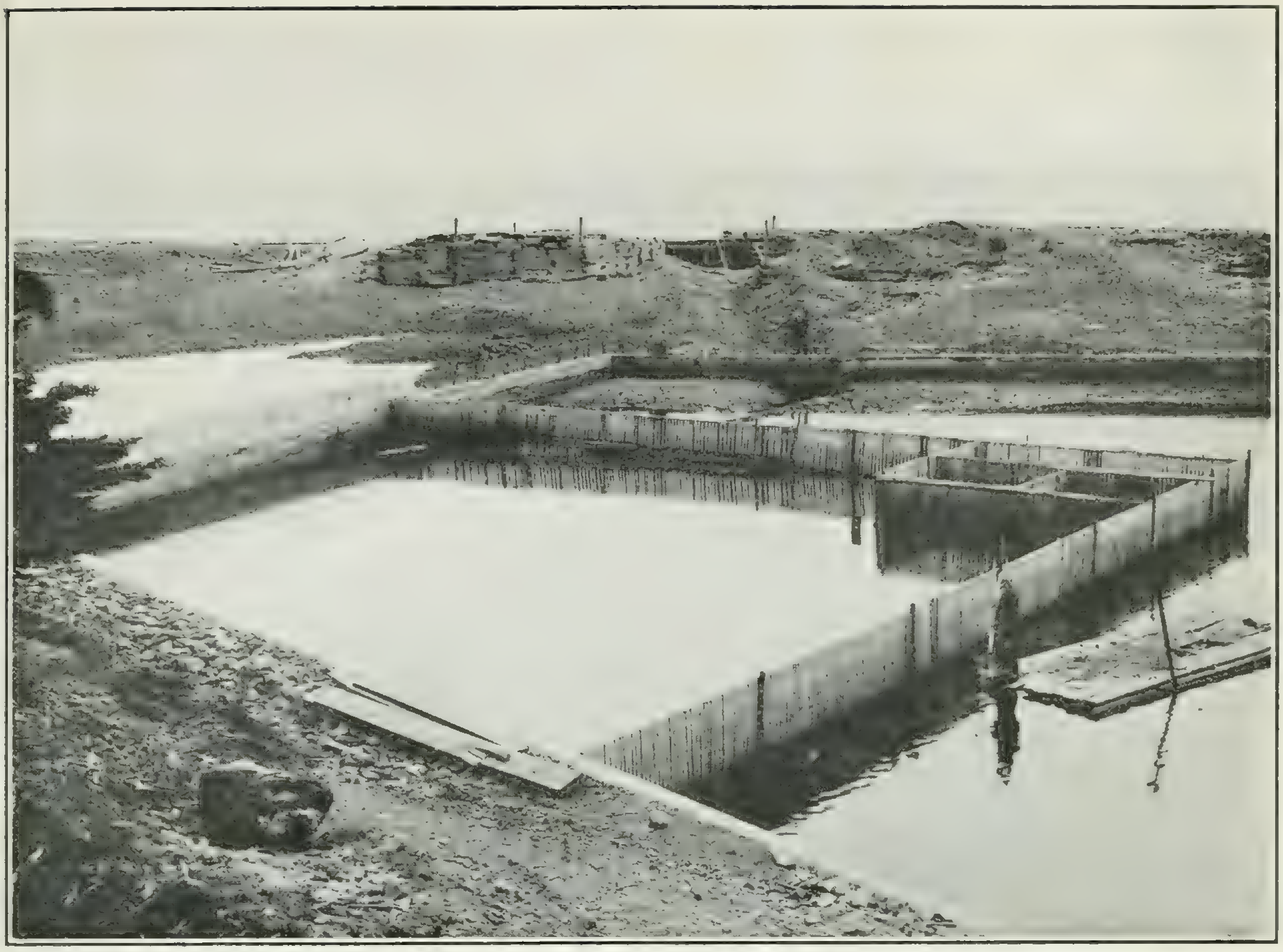


Fig. 1.—A mating pound with one large compartment and three smaller ones, all within the cement pound. The deepest water in the cement pound is immediately under the three small wooden compartments. This view was taken at about half tide, and shows the eastern side to be already bare of water. The man standing on the wall at the far side marks the position of the intake pipe.

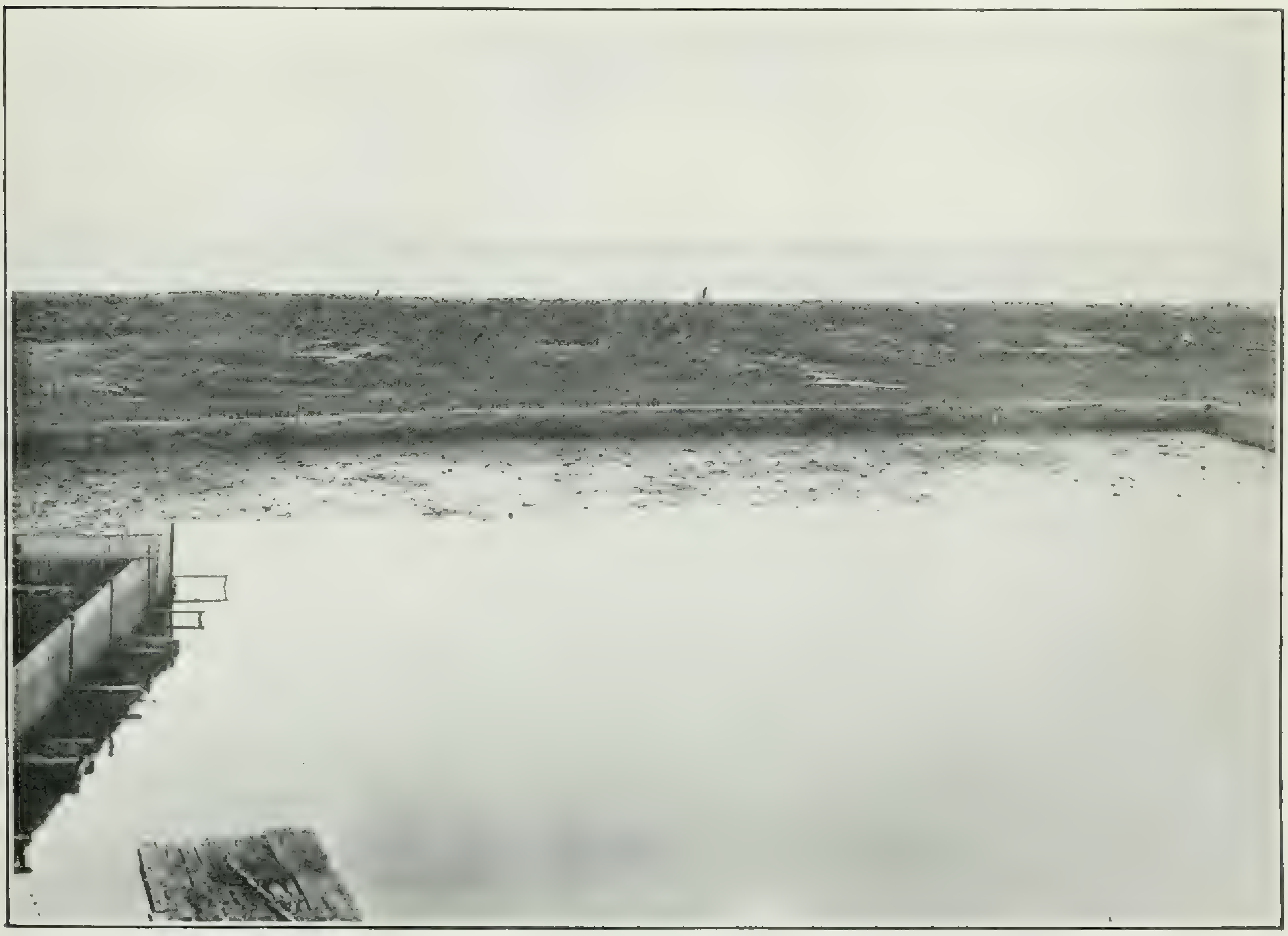


Fig. 2.—View of the eastern side of the cement pound taken near low tide. Nearly one-third of the bottom is bare of water. The rest is covered with water varying in depth from an inch to ten or fifteen inches. A small part of the wooden pound within the cement pound is shown at the left. The sea-wall is some distance beyond the cement wall, and St. Mary's bay in the background. The distant shore of the bay is faintly visible.

Fig. 1.—Sub-division of the pond marked III on the general plan, viewed at low tide. The dark patches are mud flats ; the light patches are shallow pools of water.

Fig. 2.—The plant viewed from the southwest side. A floating walk connects the engine house with the shore. The tall piles hold the rafts in place. The sea-wall is seen in the background.

"Berried" lobsters. Young females carry about 10,000 eggs on their abdominal appendages. The older and more mature ones may carry as many as 80,000.

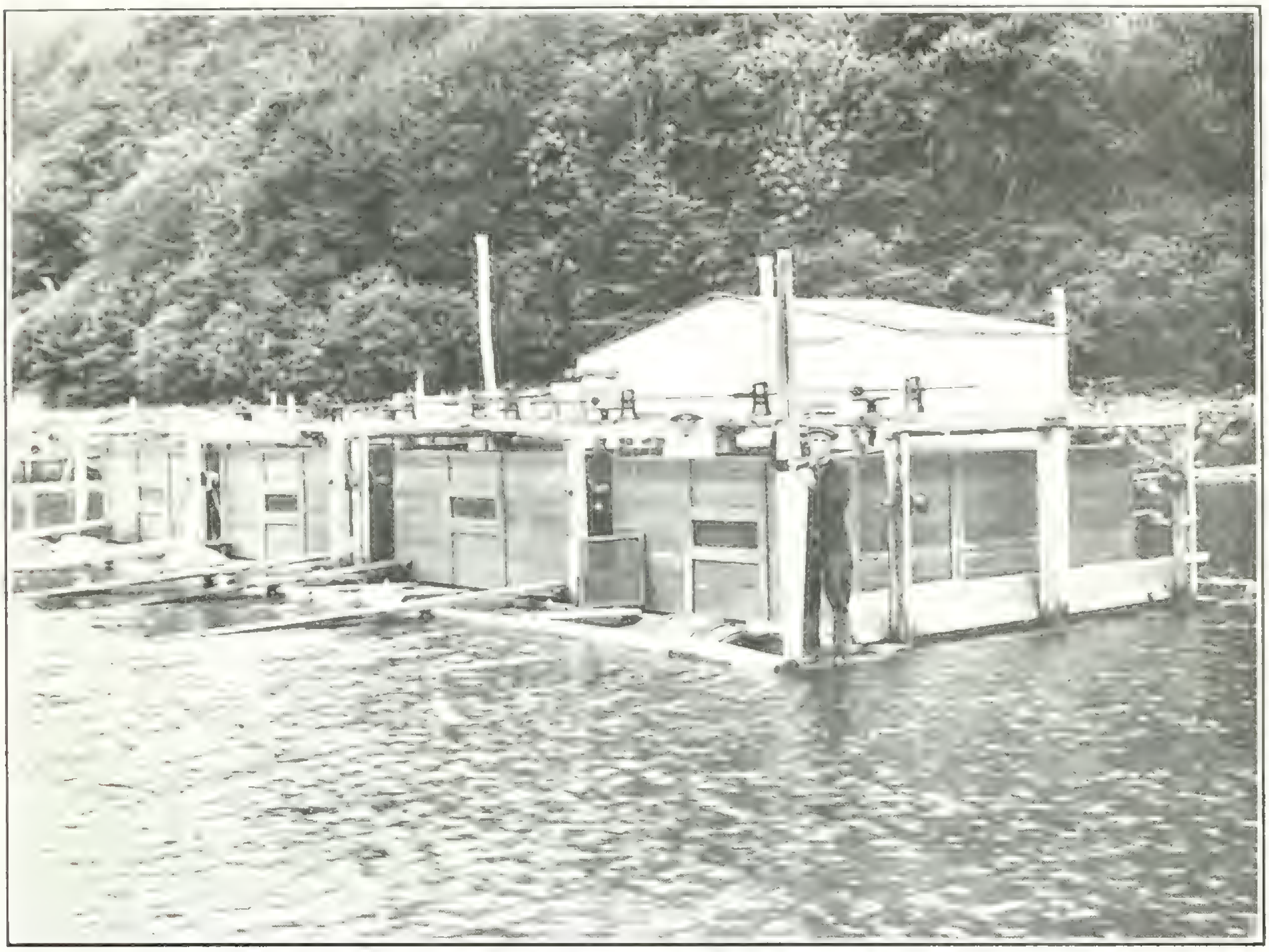


Fig. 1.—Rearing plant viewed from the east side. The four rearing or hatching boxes have been lifted out of the water. Side windows, 4 feet by 1 foot, are shown at the sides. Mr. Dawson is holding one of the paddles upright. The engine house is in the background.

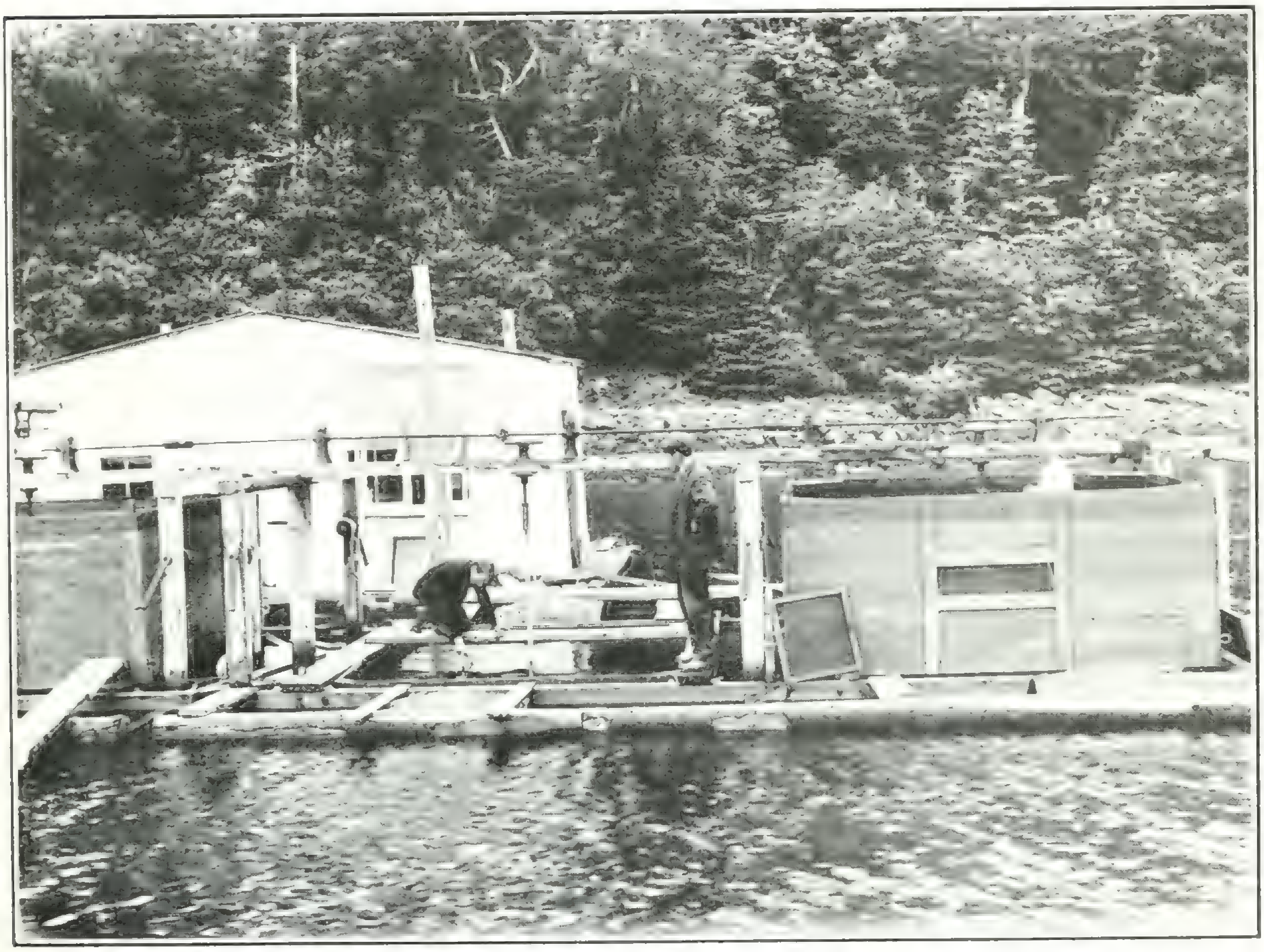


Fig. 2.—Rearing plant viewed from the east side. One of the rearing boxes is shown immersed in the water, and Mr. Dawson in the act of feeding the larvæ.

and mouth parts prevent the animals from feeding and moulting. The latter act quite differently. They are hair-like growths which penetrate the "skin" of the larvæ, and not merely prevent moulting, but suck out the juices from the bodies of the larvæ, and inevitably produce death.

WEATHER.

Another difficulty which we encountered was adverse weather conditions. At first sight it might appear strange that lobster larvæ should be subject to slight variations in weather conditions, but they are, even more so than human beings. Every one knows that when we are exposed to cold and damp and rainy weather we "catch cold," which is only another way of saying that when our vitality has been lowered by cold, disease germs enter the body all the more readily and make us sick. In a somewhat similar way, the foggy, cloudy, and cold summer at Long Beach pond last season delayed greatly the growth and moulting of the young, and gave plenty of time for disease germs to attack and kill them.

How do we know that warm water and sunlight are favourable to the growth of young lobsters, and that cold water and foggy weather are unfavourable? Very simply. We just examine the young lobsters under the microscope from day to day, and see how long it takes them to moult, that is, to change their "skin." When lobsters come out of their "shells" they are said to be in their first stage. They have no little legs or swimmerets on the under surface of their abdomen. When, however, they are properly fed, and when the water is warm and there is fair weather, they shed their skin or outside covering in from five to six days. They are then said to be in their second stage. In this stage they have short little swimmerets on the abdominal surface, and the presence of these is the chief mark by which we recognize that they are in the second stage. In three or four days more, if all conditions are favourable, the young moult again, that is, change their skin and pass into the third stage. Every time they change their skin they are said to moult and pass into another stage, and each stage is marked by some slight change in the size, shape, or colour of different parts of the beast's body.

Now, remembering what moulting means, let us return to the subject of the effect of warm and cold water upon the growth and development of lobster larvæ.

Professor Gorham has drawn up the following table showing the results of varying degrees of warm and cold sea-water upon the growth and development of lobster larvæ at different points along the Atlantic coast:—

Place.	Temperature.	Time taken from 1st to 3rd stage.
Orr's island, Maine	57°-63° F.	25 to 26 days.
Woods Hole, Mass	63°-65° F.	22 to 25 days.
Wickford, R. I	65° F.	16 days.
" "	72° F.	9 days.
Annisquam, R. I	76° F.	10 days.

Comparing these temperatures and results with ours at Long Beach we find that our temperatures ranged from 60°F. on July 17th the beginning of the hatching to 60°F., on August 22, the close of the plant. The highest temperature registered during the period was 65·2° F., July 30. Our average for the period during which the plant was in operation was 60·8° F., and we were unable to rear any lobsters to the fourth stage. The best we could accomplish was the second stage in ten days and the

third stage in six days longer. The reason we were unable to rear any to the fourth stage was that they became so greatly infected with parasites that they were unable to eat, and consequently died.

It will thus be seen that cold water retards the growth and development of larvæ, whereas warm weather promotes them. If, therefore, the policy of rearing lobsters is decided on as a permanent one for the Dominion, it will be essential that the plant be placed in the warmest sea-water along our Canadian coast.

LIGHT.

Light is another influence which profoundly affects the life of both larvæ and adult lobsters.

How quick and invariable the response to light is in the case of the young was frequently demonstrated to visitors. By transferring a number of larvæ to a basin containing sea-water and then placing the basin on a table so that direct sunlight might fall upon a small part of the water the newly hatched larvæ at once swam into the sunlight. This experiment was repeated again and again with the same results.

The conclusion to be drawn from it is clear enough. The newly hatched larvæ should be impounded in rearing boxes to which sunlight has free access. Cloudy or foggy weather in the earliest stage is unfavourable, and consequently in the selection of a locality in which to place a permanent rearing plant, careful consideration should be given to the amount of sunshine prevalent in the place.

But the young lobster does not seem to enjoy bright sunshine for any lengthened period. After it has moulted twice, and especially after it has moulted three times, the habit of basking in the sunshine changes to some extent to that of retiring from the light. In other words, it begins to take on the habit of the adult. As is well known, full-grown lobsters avoid the light. During the day they hide in burrows or under ledges of rock. In the evening they come out and roam about seeking food. Probably they move about all night, for those in sanctuaries are usually seen very early in the morning returning to their habitual haunts or shelters for the day.

It follows from the foregoing observations that as soon as larval lobsters reach the fourth or fifth stage, and adopt the habit of the adult of avoiding the light and hiding on the bottom in the mud or among the weeds, the rearing operation may cease. During the transition period between stage one, when they delight in sunshine, and stage four when they begin to avoid it, that is, during the third stage, the rearing boxes are shaded from the direct rays of the sun by a canvas covering stretched over the boxes.

It must not be imagined that cold water, cloudy weather, and microbes were the only enemies with which young lobsters had to contend in Long Beach. Eels, sticklebacks and various species of crustacea were present, the latter in vast numbers; *Mysis stenolepis* were also abundant; but above all *Idotea irrorata,* a species of isopod. All of these animals are enemies of lobster larvæ. As regards the last-named animal, an experiment which I suggested to A. R. Dawson shows that larvæ which were hatched in the pond would have but a poor chance to avoid being eaten. Mr. Dawson reports as follows:—

"On July 4, ten lobster larvæ, one day old, were placed in a basin of water, with one isopod. This was at 11 a.m. At 1 p.m. the isopod had killed eight larvæ. Only the cephalo-thorax was eaten. At one time the isopod held two lobster larvæ, one in the first and second pairs of the thoracic feet, the other in the third and fourth pairs. When the isopod had eaten the desired part of larva No. 1, it was released and allowed to float away, while larva No. 2, held in the third and fourth pairs of feet, was passed forward to be in a suitable position for being eaten.

"Almost invariably the isopods sank to the bottom of the basin as soon as they had taken their prey and rested on their backs while eating."

ANNUAL OR BIENNIAL HATCHING.

A second suggestion regarding the cement pound was that it might be used by the Biological Board for settling the question: "Do female lobsters extrude and hatch their eggs annually or bienially."

This question would appear to be already settled unless the habit of the Atlantic lobster differs entirely from those introduced into New Zealand. Professor Prince, who has always adhered to the view that lobsters spawn annually, sends me the report of the Marine Department of New Zealand for the year 1911-12. In this volume, Mr. F. Anderton, the Superintendent of the Marine Fish-hatchery at Portobello, N.Z., reports annual spawning by eleven out of fifteen lobsters in 1911, nineteen out of twenty-one in 1910, and twenty-three out of twenty-three in 1909.

If the lobsters now in Long Beach pond remain healthy during the next year, they will furnish some facts bearing upon this question.

FEEDING EXPERIMENTS.

A third suggestion that has been made regarding the cement pound is that it be used for feeding experiments. This is a proposal which every scientific worker will heartily endorse; but it is work that would be by no means easy. The pound as it stands at present cannot be used for such a purpose, because the bottom is covered with animal and vegetable matter and would thus supply some food for the lobsters. Unless, therefore, the bottom were cemented, it would be impossible to decide how much nourishment the lobsters derived from the bottom of the pound and how much from the special food supplied to them by the experimenter.

In the next place, the experimenter would need to be in a position to control all other conditions of feeding—frequency, quality, and quantity of food. Moreover, the amount and kind of excretion would have to be approximately determined; also, how much of the food is expended in the form of motion and how much in the form of heat.

When the Government, therefore, is prepared to cement the floor of the pound, which would be the very smallest part of the cost of such experiments; build compartments and shelters for the lobsters; guarantee that there shall be abundance of water throughout the year, with no danger of the animals being frozen to death in winter nor sickened by excessive heat in summer; lastly, when the Government is willing to provide salary to secure the services of a trained and experienced physiologist and provide him with a comfortable house at Long Beach throughout the year, then and not till then will it be possible to use the cement pound for experiments in the feeding and growth of lobsters. As the "balanced ration" for cattle was not discovered by an untrained farmer, so the balanced ration for lobsters will not be discovered by an untrained fisherman, who throws "gurry" at his beasts and calls the act scientific feeding.

MATING GROUNDS.

The cement pound, though of no use as a location for a rearing plant of the Wickford type, may nevertheless be utilized, I believe, for another purpose altogether. If a sufficient depth of water can be retained in it from one high tide until the next, if shelters are provided for the animals, and if they are properly cared for and regularly fed, the pond may be used as a mating ground for commercial lobsters.

That there is need for a restricted ground for mating purposes appears to be clear from the following facts: Only 10 or 12 per cent of the female lobsters caught along the Massachusetts coast are berried (see Rhode Island Fish Commission report for 1906). In St. Marys bay and the Bay of Fundy the percentage is much less. Why should not almost all the females carry eggs if their natural habit is to spawn every

year? The explanation appears to be this; the mating of male and female is largely a matter of accident. It is said that the male does not seek out the females, but "tries" every lobster he meets, male and female alike. If a female does not chance to meet a male, her eggs are not fertilized, and can produce no larvæ. The fewer lobsters, therefore, and the wider the area over which they are distributed the less the chances are for mating, and the fewer the number of berried lobsters.

As showing how restricted grounds may promote mating, and therefore, increase the number of berried females, the following facts appear to be significant: After the close season began in June (1914), the department arranged to send sixty-two commercial lobsters, forty-seven unberried females, and fifteen males to the cement pound. These were dipped up and examined about once a week. Before our plant closed (August 22) no fewer than nineteen out of the forty-seven females had extruded eggs. By the end of September nine more had extruded eggs. Not counting seven of the females which were young and under 9½ inches in length, the number extruding eggs (twenty-eight) would amount to 70 per cent of the forty females, a most extraordinarily high percentage.

How else can we explain this high percentage excepting on the hypothesis that the restricted area within which they were confined promoted mating? Whether the eggs have been fertilized or not can only be determined by examining them from time to time and watching for the development of the embryo—an easy task for any well-trained biologist.

In connection with this subject it is worth while to refer to the catch of 3,000 lobsters made in 1913 by Mr. Joseph W. Tidd, of Whale Cove, Digby county, Nova Scotia. Mr. Tidd used 175 traps. The traps were set along the bay of Fundy, about a mile northeast of Petite passage, and a quarter of a mile from shore. While the number of males and females were about equal, only three of the latter bore eggs. Why were there not about 700 berried females in place of three, if female lobsters extrude eggs biennially? Why were there not about 1,500 berried females if they extrude their eggs annually? On either supposition there must be a very high percentage of sterile females, or else, after extruding eggs in any season, they lose their eggs in some way which we do not as yet understand, but simply guess at.

To me the simplest explanation is that the facilities for mating are lacking. There is and has been much over-fishing in the bay, and the animals are scarcer and farther apart than they used to be. Moreover, lobsters are known to be eminently local in their habits, and do not wander far from their natural burrows or shelters. Perhaps their movements are restricted by the strong tidal currents which prevail in the bay. These are possible reasons why there is relatively little mating and therefore few berried females. Assuming that this is the true explanation, one can readily see the tremendous advantage of mating grounds. For after all is said and done, there are only three important ways in which we can increase our lobster supply: (1) by increasing the numbers of females which carry eggs; (2) by rearing the larvæ to the fourth or fifth stage, and there is some doubt as to whether this can be done economically; and (3) by limiting the catch of the larger and more mature males and females. If some temporary tidal enclosures are constructed here and there along the coast, as suggested elsewhere in this report, they could be used as mating enclosures for commercial lobsters as soon as the open season has ended and the berried females have been liberated in the sea.

CONSTRUCTION OF THE PLANT.

The carpenter work was ready for the shafting and gearing on June 23, but the machinery was unfortunately delayed in transportation for over a fortnight at St. John, and did not arrive until July 10. The rearing plant was started on its regular work on July 17, and ran exactly one month, when our supply of hatching lobsters

gave out. If our machinery had not been delayed in transit, we should probably have been able to complete three hatchings; but it is not likely that the results would have differed much if at all from those recorded in the preceding pages.

THE MECHANISM OF THE REARING PLANT.

The mechanism of our plant is very simple. It consists of three skeleton rafts which are buoyed up by empty molasses puncheons. One of the rafts carries the engine house, the other two carry two rearing boxes each.

The foundation structure of the two rafts which carry the four rearing boxes is easily understood. If looked at from above, it would present the following appearance:

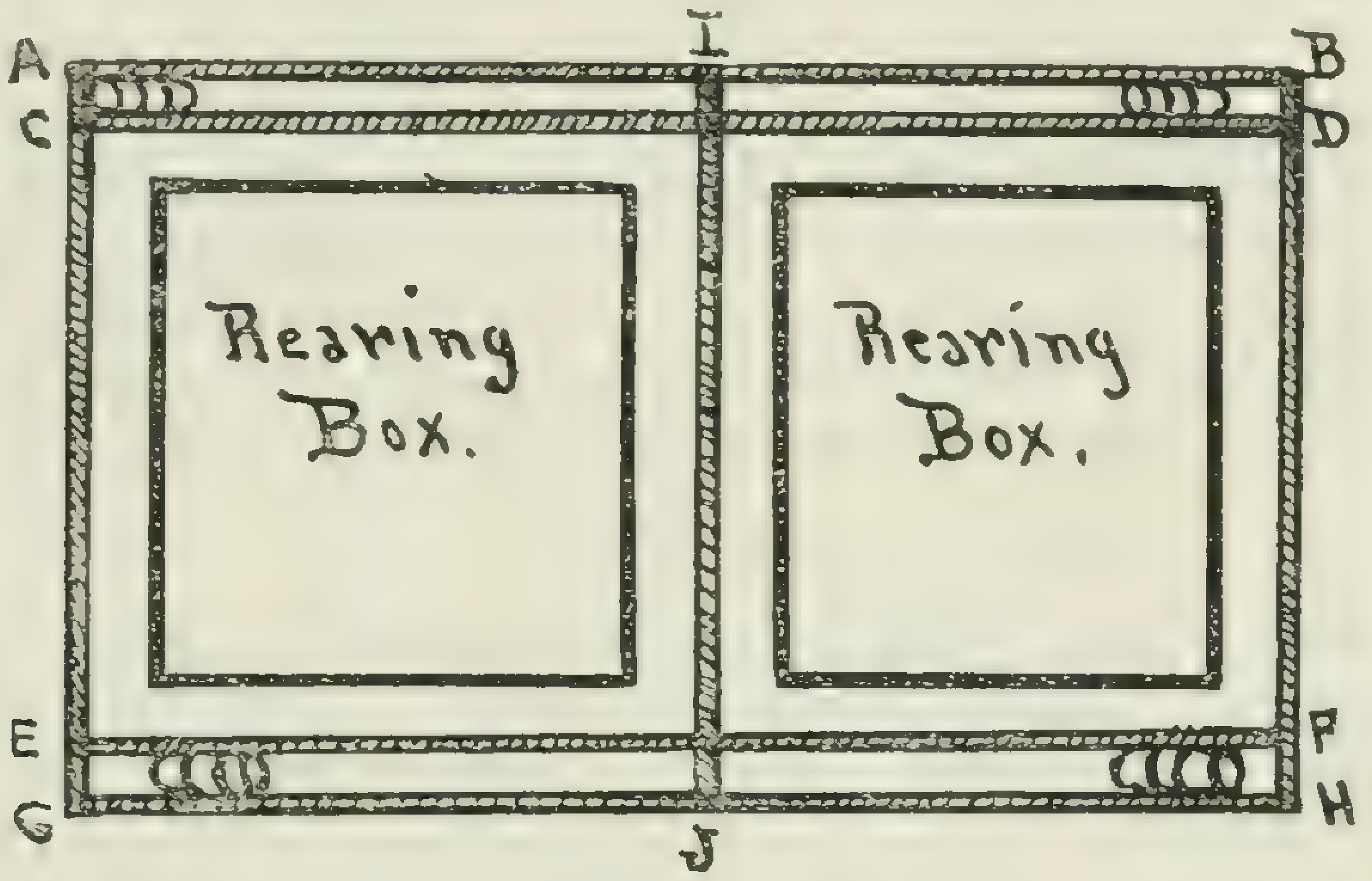


Fig. 2.—Foundation of a Raft.
(Drawn by A. B. Klugh, M.A.)

AB, CD, EF, GH, are parallel pieces of spruce timber 6 inches by 6 inches, A, G, I J, and B H are cross-timbers of the same size. They are all firmly bolted together and make up the floating part of the raft. At the four corners are fastened four large molasses puncheons.

The third raft differed from the other two only in the fact that it supported the engine house and, on account of the extra weight which it had to carry—engine, shafting, tools, etc., it was buoyed up by eight puncheons in place of four.

REARING BOXES.

Inside of the two largest areas of the skeleton rafts are placed two hatching or rearing boxes. These measure 10 feet by 10 feet by 4 feet, and are made of planed matched spruce boards $\frac{7}{8}$-inch thick, and carefully put together so as to prevent the escape of the larvæ. There are no openings into the boxes exceeding $\frac{1}{16}$-inch. Each box has four windows in it; two in the bottom, 2 feet by 2 feet, and two in opposite sides 4 feet by 1 foot. These are screened with bronze or brass cloth of $\frac{1}{16}$-inch mesh.

Each box is lowered into the water about $3\frac{1}{2}$ feet and kept there while the apparatus is in operation. On each of the rafts which support the hatching boxes is an elevated framework of timber 4 feet by 6 feet and 5 feet high, built for the support of the machinery which is used in making the water circulate. This superstructure, with its accompanying shafting and gearing, can be understood by looking at Plate VII.

When the plant is in operation, the rearing boxes are held down in the water by two planks, one at each end of a box, and the paddles, which will be described presently, are kept revolving at the rate of between eight and nine times per minute. When not

in operation, as between finishing with one batch of larvæ and starting a second batch, the boxes are raised from the water, dried, and their inside given a fresh coating of copper paint in order to prevent the parasites that may have infected one batch from infecting the following one.

PADDLES.

The paddles are paired structures about 9 feet long. Ours were 8 inches broad at one end and tapered gradually to 4 inches at the other. They were attached to 1 inch gas piping by clips such as are commonly used by plumbers in fastening gas piping to walls. The action of the paddles is such as to draw fresh salt-water in through the windows on the bottom of the rearing box, give it a circular and upward movement in the box, and pass it out through the side windows. This purpose is accomplished by setting the front edge of each paddle slightly downward. In this way, not merely was the water made to circulate, but its velocity could be adjusted, a most important thing in the rearing of the fry, according to officials at Wickford. The velocities used at Long Beach, estimated by the length of time it took a light cork to float in the water around a circle of 15 feet circumference were 1 foot per second, down to 1 foot in 1⅜ seconds. The writer was unable to see any differences between the effects of these two velocities on the larvæ, the dominant factors being the low temperature of the sea-water and the excessive development of plant parasites.

THE POWER.

Our motive power was a two-horse-power horizontal engine made by the Fairbanks Morse Company. Though it was required to move the paddles in only four boxes, the pond is so sheltered from winds in every direction that the engine could easily generate sufficient power to run the machinery of a full Wickford plant of twenty-four boxes. In fact, if it is found after next season that the pond is not suitable for a permanent rearing plant, the engine and gearing can be removed and the equipment tried elsewhere. After the first week, during which the batteries and the wiring gave us some trouble, the engine ran for nearly a month, day and night, with only a few short stoppages for cleaning and adjustment.

ROUTINE WORK.

As soon as a sufficient number of larvæ were placed in the four boxes, regular routine work was established. The first step, of course, was to secure a sufficient number of mother lobsters whose eggs were all hatching at the same time. Eight or ten of these were placed in one of the boxes, and at the end of two days a sufficient number of larvæ had hatched out to stock another box. Two of the staff were detailed to count out between 5,000 and 8,000 fry by means of a dip net. An automatic counter held in one hand and operated by the thumb enabled each man to count out the exact number of larvæ which it was desired to transfer to each box.

All the boxes having been stocked in this way, routine work consisted in arranging a division of the work among the staff. For most of the time there were only three of us, and consequently each man was on duty for eight hours out of the twenty-four. The longest watch was felt to be the one lasting from 11 p.m. until 7 a.m. the next morning. During each watch the engine had to be supplied with gasolene, with water for cooling the cylinder, and with plenty of oil for lubrication. In addition to these duties, each man during his watch had to scramble eggs or macerate liver or mackerel and feed the fry every two hours. The work was anything but a "summer outing," though some of the local people evidently thought so at first. Possibly, reader, you may think so, too. But if you had taken your turn at the work, night and day, Saturdays and Sundays, week in and week out, for a month; and if in addition you had attempted to carry on some systematic scientific research during the day, your little delusion about our experiments being a summer outing would soon have been dispelled.

V.

FIRST REPORT ON THE "BARREN OYSTER BOTTOMS" INVESTIGATION, RICHMOND BAY, P.E.I.

By A. D. Robertson, B.A., *University of Toronto.*

In this investigation, which began early in May and was carried on until the middle of September, 1914, the following points were considered:—

1. Nature of the bottom in the various parts of the area.
2. Extent of level portions and of banks and deep gullies.
3. Depths in the various parts of the area.
4. Presence of eel-grass and seaweeds.
5. Salinity.
6. Temperatures at top and bottom.
7. Plankton and floating oyster food.
8. Inflow and amount of fresh water; number of flowing streams.
9. Presence of oyster enemies, starfish, drill, whelk, etc.
10. Occurrence of small oysters as evidence of spatting.
11. Occurrence of dead oyster shells, as evidence of former production.
12. Freezing to bottom in winter.
13. Time of spawning.
14. Time and extent of spatting.
15. Former output of the bay.

NATURE OF THE BOTTOM IN THE VARIOUS PARTS OF THE AREA.

Dredgings and soundings were made in the various parts of the bay for the purpose of investigating the nature of the bottom, but owing to the lack of proper facilities for ascertaining the exact location of the individual soundings and dredgings, an accurate map of the nature of the bottom cannot yet be given. The account of the bottom given here is also quite general.

The bottom consists for the most part of the red sand, so characteristic of Prince Edward Island. Rocky areas, composed of red sandstone, extend out from several points of the islands and of the mainland. In the deeper places the sand is mixed with a higher percentage of humus forming, in certain locations, a very soft black mud into which a pole can be shoved for several feet. Shell beds (oysters and quahaug) are found scattered over the mud areas and on the edges of the sand areas, while oysters are plentiful on the rocky points.

In the Inner bay or March Water (that portion of the bay between the Curtain islands and the Shipyard river), the sandy area extends around the shore along the south of Grover (Ram) island, across to Princetown point and on to Malpeque wharf and the Shipyard river. Thence it follows the south shore to Beech point, where it turns northward along the Curtain islands. The width of this area is not at all uniform. An extension southward from Princetown point forms the Middle Ground shoals which are separated from the point by only a shallow channel. The sandy area also extends out somewhat farther from the points on either side of the mouth of the Shipyard river and is more extensive, too, near Beech point and along Curtain (Little Curtain) and Bunbury (Curtain) islands. Patches of rock occur east of the Curtain islands, to the northwest of the Middle Ground shoals, and to the northeast

of Beech point. The muddy area comes in from the outer bay between Grover and Bunbury islands, widens out in the Inner bay, where it is encroached upon by the Middle Ground shoals and finally narrows down towards the mouth of Shipyard river. Oyster beds are found in that portion of the area, around the Middle Ground shoals and in that which lies between these shoals and the Shipyard river. They are, however, not very numerous.

In the Big bay (that part of the bay south of the line joining Charles point (cape Malpeque) and the north end of Bunbury island, the sandy area sweeps south along the Curtain islands, over to Beech point and on past Oyster cove to the Indian river. Thence it continues along the south shore past the Barbara Weit and Plat rivers to Shemody creek, from which it extends along the west shore to Charles point. As in the Inner bay, this area is everywhere of considerable width, but is especially wide in some places. This is particularly the case off Bentinck (Fraser's) point where the Bentinck shoals stretch out far into the bay and are separated from the point by a quite shallow channel. Rocky areas are found, in this part of the bay, west of Bunbury and Curtain islands, south of Beech point, off Taylor's, Chichester (Mill's), and Webber's (Townsend's) points, and from Charles point well down towards Bentinck point. The deeper muddy portion enters between Charles point and Bunbury island and extends towards the Indian and Barbara Weit rivers, sending off a long spur to the mouth of the Shemody creek. Oyster beds are numerous, widely distributed and extensive in this part of the bay.

In the Outer bay (that part of the bay north of Charles point, Bunbury island and Grover island) a sandy area extends from Royalty point past Princetown point to Grover island, a very extensive area stretches out to the north and northwest from Bunbury island, a third reaches from Charles point to the mouth of the Grand river, while another wide area lies along the west shore from the Grand river past Bald, Red, and Gillies (Low) points into the narrows between Lennox island and the mainland. Further and very extensive sand areas lie south from Middle (Bird), George (Hog), and Bill Hook (Fish) islands. The areas last mentioned, interrupted by channels of moderate depth, are continued into the shoals known as the Horseshoe shoals. In this part of the bay the rocky stretches are larger than those previously mentioned in this report. Extensive rocky areas are given off from the north of Grover and Bunbury island and Charles point, and also south from George island. Less extensive areas lie out from Campbell's pond on the west shore, in an area halfway between Charles point and the mouth of the Grand river, and also out from Bald point between the Grand river and Gillies point. The deeper portion of the bay enters between Bill Hook island and Royalty point, runs south of the Horseshoe shoals and, after giving off the two branches already referred to as entering the Inner and Big bays, and also a third running to the Narrows and the mouths of the Bideford and Trout rivers, continues southwesterly to the Grand river. Oyster beds do not occur in the deep muddy portions of this part of the bay although they do occur on the sandy area running out from Bunbury island.

The sandy areas are covered with eel-grass out to depths of 8, 10 or 12 feet. The rocky areas usually have a covering of seaweed.

It should be understood that the transition from the sand areas to the mud areas is a gradual one.

EXTENT OF LEVEL PORTIONS AND OF BANKS AND DEEP GULLIES.

The whole bay is remarkably level, and as a rule there are few rapid changes in depth. The deep channels have been referred to in the paragraphs dealing with the nature of the bottom. The channel enters the bay between Bill Hook island and Royalty point, runs westward south of the Horseshoe shoals to a point north of Bunbury island. Here the four branches mentioned above radiate. One enters the inner bay between Grover and Bunbury islands and passing south of the Middle Ground shoals reaches the Shipyard river. Another extends west of Bunbury island south-

ward into the Big bay towards the Indian and Barbara Weit rivers, and sends off a branch to Shemody creek. A third branch goes to the Grand river and a fourth to the Narrows between Lennox island and the mainland. These channels are for the most part wide and have fairly level bottoms.

The sandy areas near shore are also very level, sloping out gradually to the deep channel and showing a somewhat more abrupt incline on the edges of the latter. The slopes are somewhat more abrupt than usual on the sides of the Bunbury sands and of the Middle Ground shoals facing the main channels. Abrupt slopes occur also among the Horseshoe shoals.

DEPTHS IN THE VARIOUS PARTS OF THE AREA.

This portion of the investigation has not been completed and the work done on it is withheld, for publication in a later report. Only a very general account is given here. The greatest depth at the entrance of the bay, between Bill Hook island and Royalty point is 53 feet. There are places in the channels among the Horseshoe shoals which are at least 27 feet deep, while parts of the shoals are covered by about 3 feet of water. The channel into the Inner bay has a depth, between Bunbury and Grover islands, of 24 feet, and south of the Middle Ground shoals of 17 feet, while over parts of the shoals the depth is not more than 2 feet. The channel leading into the Big bay has a depth northwest of the Bunbury sands of 42 feet, west of the northern end of Bunbury island of 35 feet, west of its southern end of 32 feet, towards the Indian and Barbara Weit rivers of 14 feet, and towards Shemody creek of 15 feet. The Bentinck shoals are covered in places by about 2 feet of water. The channel at the ferry Grand river is 30 feet deep, and that approaching the Narrows between Lennox island and the mainland is 24 feet in depth.

PRESENCE OF EEL-GRASS AND SEA-WEEDS.

Eel-grass (*Zostera marina* L.) is very abundant everywhere on the sandy areas in depths up to 10 or 12 feet. It borders the shore of the whole bay except where there are rocky areas, and it is also found on the Horseshoe, Bentinck, and Middle Ground shoals. In many other and deeper places, dredgings show that quantities of dead and decaying eel-grass are lodged on the bottom. In the late summer and, according to reports, to a greater extent in the autumn, the storms tear loose quantities of eel-grass which are swept together into great masses and rolled in upon the shore. This eel-grass is gathered up and used as a fertilizer, or to bank buildings against the cold. The oyster companies do good work in removing the grass from their plots, but too often set it adrift in other parts of the bay instead of taking it ashore. When only small areas are cleared the loose eel-grass rolls over the bottom into the hollows, formed in the process of clearing these areas, and lodges there. Because of this, some of the companies have to clear their areas after each big storm. Eel-grass is detrimental to good catches of spat. In no case was there a good set on any of the collectors set among eel-grass.

Seaweeds are found on the rocky areas. In many cases the rock is well covered, and here the seaweed must interfere with the set of spat. In some places kelp (*Laminaria saccharina* Lamx.) is found attached to the oysters, and must, at times, when from any cause they are not attached to the bottom, result in their being carried to unfavourable localities.

The Marine algæ collected during the summer were sent to A. B. Klugh, M.A., of Queen's University, Kingston, and he has very kindly identified them. The collection is not very extensive, specimens which were taken in the dredge, or in the plankton net, alone being represented.

The following account gives the date and place of collection as well as the species collected:—

July 20.—Curtain Island shoal: *Lyngbya aesturia* Lieb., *Nodularia harveyana*, Thuret.

July 24.—Low Point: *Chordaria flagelliformis* Ag., *Gelidium crinale* (?) Ag.

July 24.—East of Low point: *Chondrus crispus* Stack., *Gelidium crinale* (?) Ag.

July 24.—Outer bay, midway between Bunbury island and Gillies point: *Gelidium crinale* (?) Ag.

July 25.—Gillies point: *Ectocarpus confervoides* Le Jolies, *Castagnea virescens* Thuret.

July 25.—East of Gillies point: *Polysiphonia urceolata* Grev., *Cladophora laete-virens* Dillw., *Anabaena variabilis* Kuetz., *Nodularia harveyana* Thuret., *Lyngbya aestuaria* Lieb.

July 28.—Bentinck point: *Gelidium crinale* (?) Ag., *Gelidium corneum* L., *Ectocarpus littoralis* Lyng.

July 30.—Bunbury island: *Ectocarpus confervoides* Le Jolie.

August 8.—Bunbury island: *Chordaria flagelliformis* Ag., *Chorda filum* L., *Chondrus crispus* Stack., *Gigartina mammillosa* J. Ag., *Laminaria saccharina* Lamx., *Gelidium crinale* (?) Ag.

September 3.—Grand river, below the ferry: *Cladophora laete-virens* Dillw., *Ulothrix flacca* Thuret.

The following species were preserved in bottles, from which the labels were lost: *Scytosiphon lomentarius* Ag., *Chondrus crispus* Stack., *Gigartina mammillosa* J. Ag., *Laminaria saccharina* Lamx., *Monostroma fuscum blyttii* Collins, *Entomorpha intestinalis* Grev., *Enteromorpha compressa* Grev., *Porphyra umbilicalis* J. Ag., *Gelidium crinale* (?) Ag.

Twenty species in all are recorded. This number will no doubt be greatly increased by the collections to be made in 1915.

SALINITIES AND TEMPERATURES AT TOP AND BOTTOM.

Salinities and temperatures were taken in many places in the bay at various times throughout the summer. The following is the list of locations:—

1. Narrows, west of Indian Chapel.
2. Narrows, near Sharp's beds "Rock bed".
3. West of Grover island.
4. Mouth of Indian river.
5. Bell bed, Grand river.
6. Mouth of Macdonald creek, Grand river.
7. Below bridge, Grand river.
8. Second bed below ferry, Grand river.
9. First bed below ferry, Grand river.
10. Old dump, Inner bay.
11. Wharf, Bideford river.
12. Bed southeast of second barrel buoy, Inner bay.
13. Plot 128 east of Bunbury island.
14. Plot 123 east of Bunbury island.
15. Plot 133 east of Bunbury island.
16. Plot 127 east of Bunbury island.
17. Plot 142 east of Bunbury island.
18. Plot 124 east of Bunbury island.
19. Off Bald point, Outer bay.
20. Little Curtain Island bed, Big bay.
21. Mouth of Plat river.
22. Mouth of Shemody creek.
23. Middle of channel south of Shemody point.
24. Mouth of Indian river.
25. Near mouth of Indian river.
26. Mouth of Barbara Weit river.

SALINITIES AND TEMPERATURES AT TOP AND BOTTOM—*Continued.*

27. South of Taylor's point.
28. Off Taylor's point.
29. Off Wait's point near mouth of Barbara Weit river.
30. Mouth of Oyster cove.
31. Sharp's "Peter Creek" bed, Narrows.
32. Third bed below ferry Grand river.
33. Burke cove, Grand river.
34. West of Charles point.
35. Lot 11, Grand river.
36. Southeast of Red point, Outer bay.
37. Off Charles point.
38. South of Bunbury island.
39. South of Bunbury island.
40. Off the north point of Bunbury island.
41. Plot 194 near Middle island.
42. Plot 300 near Middle island.
43. Plot 298 near Middle island.
44. Plot 196 near Middle island.
45. Plot 246 near Midle island.
46. Plot 197 near Gillies point.
47. Plot 200 near Gillies point.
48. Plot 294 near Gillies point.
49. Plot 297 near Gillies point.
50. East of Gillies point.
51. Middle of Outer bay, Gillies point, and north of Bunbury island in line.
52. Inman's bed, Shemody creek.
53. East of Shemody point.
54. East of Bentinck point.
54a. East of Simpson's Point.
55. Plot 378, Big bay, near Bunbury island.
56. Plot 428, Big bay, near Bunbury island.
57. Plot 424, Big bay, near Bunbury island.
58. Plot 425, Big bay, near Bunbury island.
59. Channel between Grover and Bunbury islands.
60. Plot 375, Big bay, near Bunbury island.
61. Plot 268, Big bay, near Bunbury island.
62. Plot 332, Big bay, near Bunbury island.
63. Plot 266, Big bay, near Bunbury island.
64. Plot 430, Big bay, near Bunbury island.
65. Plot 372, Big bay, near Bunbury island.
66. Plot 267, Big bay, near Bunbury island.
67. Plot 467, Big bay, near Bunbury island.
68. Plot 370, Big bay, near Bunbury island.
69. Plot 283, Big bay, near Bunbury island.
70. Plot 284, Big bay, near Bunbury island.
71. Plot 340, Big bay, near Bunbury island.
72. Plot 434, Big bay, near Bunbury island.
73. Plot 315, Big bay, near Bunbury island.
74. Plot 387, Big bay, near Bunbury island.
75. Plot 436, Big bay, near Bunbury island.
76. Channel between Bill Hook island and Royalty point.
77. Wharf, Malpeque.
78. Shipyard river.
79. First barrel buoy, Inner bay.
80. South side of gap between Grover island and Princetown point.
81. South of Grover island.
82. Northeast of Grover island.
83. North side of gap between Grover island and Princetown point, west end.
84. North side of gap between Grover island and Princetown point, middle.
85. North side of gap between Grover island and Princetown point, east end.
86. South shore Big bay, midway between Princetown and Royalty points.
87. South shore Big bay, towards Royalty point.
88. Shoals near Bill Hook island, Big bay.
89. Middle of Horseshoe Shoals, Big bay.
90. West of south point of George island, Big bay.
91. Off southeastern point of Middle island.
92. Channel between Beech point and Curtain island.
93. South of Curtain island.
94. South of Bunbury island.
95. Little Curtain island bed, Big bay.
96. Little Curtain island bed, Big bay, edge of bed.
97. Mouth of Indian river, right bank point.
98. Chicester (Mill's) mouth of Indian river.
99. Mill's point, mouth of Barbara Weit river.

SALINITIES AND TEMPERATURES AT TOP AND BOTTOM—*Concluded.*

100. Waite's plot, mouth of Barbara Weit river.
101. Off mouth of Webber creek.
102. Off Webber point.
103. Mouth of Plat river.
104. Off Compton point.
105. Southwest of Shemody point.
106. Northeast of Shemody point.
107. North of Bentinck point.
108. Southeast of Charles point.
109. West of Bunbury island.
110. Gap between Bunbury and Curtain islands.
111. Midway between Charles point and south end of Bunbury island, Big bay.
112. Midway between Charles point and Black point, Outer bay.
113. End of Sixteen wharf, Grand river.
114. South shore Grand river, point below R. C. church .
115. North shore Grand river, opposite Southwest arm.
116. Bell's point, Grand river.
117. Black point, Grand river.
118. Off McIntire's pond, north shore near Grand river.
119. Off Red point, Outer bay.
120. Off point left shore mouth Brown's creek, Outer bay.
121. Point above wharf, Bideford river.
122. Lowest point, left shore above mouth, Trout river.
123. Sharp's point, Bideford river.
124. Sharp's bed (Rock bed), Narrows.

TABLE of Physical Properties.

Station.	Date.	Time.	Tide.	Depth.	Temperature top.	Temperature bottom.	Specific Gravity top.	Specific Gravity bottom.	Chlorine.	Total Solids.
									p.c.	p.c.
1	June 9..	11.00	Going out......	21					1·509	2·721
2	" 9..	12.00	" ...	5					1·587	2·861
3	" 9..	3.00	Coming in.....	8					1·6325	2·9435
4	" 11..	2.00	Low...........	12·5	56·5	55			1·627	2·934
5	" 12..	11.00	Going out......	3	56	56				
6	" 12..	3.00	Low...........	7	58	57				
7	" 15..	12.00	High	8	60	58·5			1·436	2·589
8	" 15..	2.00	Going out......	17	56·5	52·5			1·641	2·959
9	" 15..	3.00	" ...		58·5	23.5				
10	" 15..	6.00	Low...........	12	58·5	55				
11	" 19..	2.00	Coming in.....	10					1·454	2·621
10	" 20..	2.00	"	7	62	60			1·569	2·829
12	" 22..	3.00	"	10	61	58·5			1·579	2·847
13	" 23..	12.00	Low...........	17	63·5	55				
14	" 23..	10.00	"	16	66	55·5				
15	" 23..	3.00	Coming in.....	30	63	23·5				
16	" 25..	11.00	Going out.....	7	63	58				
17	" 25..	3.00	Coming in	22	61	57			1·694	3·152
18	" 26..	2.00	Low.....	4·5	63·5				1·655	2·984
19	" 27..	11.30	Going out......	10	58	57				
12	" 29..	11.00	"	8	60·5					
5	July 2..	3.00	"	2·75	65	62·75				
20	" 3..	2.30	High.	20	63				*1·627* 1·619	*2·934* 2·919
21	" 4..	10.00	Low...........	8	63					
22	" 4..	3.00	Coming in.....	5	67				1·588	2·864
23	" 7..	12.00	Low...........	8	67	65	1·0226			
24	" 9..	10.00	Going out......	5	69					
25	" 9..	12.40	Low...........	3·75	70		1·0216	1·0216	1·581	2·851
26	" 10..	2.30	Coming in......	3·5	77		1·0222	1·0222	1·627	2·934
27	" 10..	4·00	"	4·5	76		1·0209			
28	" 11..	9.00	High	6	68					
29	" 11..	10.00	Going out......	5·5	67	66	1·0221	1·0223		
30	" 11..	12.00	"	8	68	67	1·0222	1·0220		
31	" 13..	12.30	"	5	69·5	69	1·0228	1·0222	1·606	2·8965
5	" 14..	10.00	High..........	4	69	68	1·0229	1·0226		
9	" 14..	12.00	Going out......		69					
8	" 14..	1.00	"		69					
32	" 14..	2.00	"		70	67·5	1·0230	1·0230		
33	" 14..	3.30	"	17	70					
34	" 15.	10.00	Coming in......	5	62					
35	" 15..	1.00	Going out......	15	67·5	64	1·0231	1·0224	1·672	3·015
19	" 15..	2.00	"	13	67					
36	" 16..	10·45	Coming in......	9	67					
37	" 17..	11.00	"	7	71	70	1·0224	1·0224	*1·657* 1·631	*2·988* 2·941
38	" 17.	1.40	High..........	27	68					
39	" 17..	2.00	"	4	69		1·0223	1·0223	1·653	2·981
12	" 20..	11.30	Low...........	17·5	75·5		1·0216	1·0216	1·590	2·869
40	" 21..	9.00	Going out.....	5	70	65	1·0232	1·0221	1·634	2·947
41	" 24..	3.30	Coming in......	17·5	67					
42	" 24..	3.40	"	8·75	68					
43	" 24..	3.50	"	22	67·5					
44	" 24..	4.00	"	4	69·5					
45	" 24.	4.10	"	22	67					
46	" 25 .	10.00	Going out.....	7	67·5					
47	" 25..	10.30	"	24	66·5					
48	" 25..	11.00	"	26	68					
49	" 25..	11.30	"	22·5	67·5					
50	" 25..	3.20	Coming in......	24	68·5	65	1·0223	1·0226	*1·621* 1·631	*2·922* 2·941
51	" 25..	4.00	"	30	68·5	66·5	1·0225	1·0224	*1·679* 1·638	*3·023* 2·9535

TABLE of Physical Properties—*Continued.*

Station.	Date.	Time.	Tide.	Depth.	Temperature top.	Temperature bottom.	Specific Gravity top.	Specific Gravity bottom.	Chlorine.	Total Solids.
									p. c.	p. c.
52	July 27..	12·00	Going out......	5	68·5	68	....	......	1 5675	2·826
53	" 27..	1·10	"	8	69	....	....	....	....	....
54	" 27..	1·53	"	12	68	....	....	....	....	....
55	" 28..	10.00	High..........	5·5	68	....	....	....	....	....
56	" 30..	1.00	"	36	66	....	....	....	..	....
57	" 30..	1.15	Going out......	14	66	....	....	....	....	....
58	" 30..	1·45	"	13	66	....	....	....	....	....
59	" 30..	2·15	"	16	66	....	....	....	....	....
60	Aug. 1..	12·00	Coming in......	27	....	....	1.0214	1·0214	1·616 1 614	2·913 2·909
61	" 4..	9·30	Going out......	21	....	....	1·0224	1·0223	1·641 1 626	2·958 2·931
62	" 4..	11.30	Low..........	36	66	....	....	....	....	....
63	" 4..	12·05	"	19	65·5	....	....	....	....	......
64	" 4..	1.35	Coming in.. ..	33	66	....	....	....	....	....
65	" 4..	2·45	"	8	67	....	....	....	....	....
66	" 4..	3·15	"	15	66·5	....	....	....	....	....
67	" 4..	3·55	"	30	66	....	....	....	....	....
68	" 5..	12·30	Low..........	12·5	66	....	....	....	....	....
69	" 5..	12·50	"	13	66	....	....	....	....	....
70	" 5	1·10	Coming in......	19·5	66·75	....	....	....	....	....
71	" 5..	1·15	"	30	66	....	....	....	....	....
72	" 5..	3 45	"	44	67	....	....	....	....	....
73	" 6..	2·00	"	17	67	....	....	....	....	....
74	" 6..	3·00	"	33	67	....	....	....	....	....
75	" 6..	3·20	"	18·5	67	....	....	....	....	....
76	" 7..	3.00	"	27	66·5	....	....	....	....	....
77	" 14..	2·00	Going out......	50	....	....	1·0224	1·0224	1·631	2·941
78	" 25..	7·00	Coming in......	4	56	56	....	....	....	....
78	Sept. 1..	8.00	Going out......	4	62·25	61·75	1·0216	....	....	....
79	" 1..	8·30	"	2	63	63·25	1·0189	....	....	....
80	" 1..	9.00	"	....	....	....	1·0218	1 0219	1·600 1·609	2·885 2·9005
81	" 1..	9.30	"	2·75	65	65	1·0221	....	1·6505	2·976
82	" 1..	10.45	Low..........	14	63·75	63·5	....	....	....	....
60	" 1..	11.20	Coming in.....	30	64	63 5	1·0223	1 0222	....	....
83	" 1..	11.50	"	2 5	66	65·5	1.0223	1·0222	....	....
84	" 1..	12.20	"	1	67	67	1·0224	....	....	....
85	" 1..	12 50	"	2	65	65	1·0220	....	....	....
86	" 1..	1.30	"	2	69	....	1·0225	....	....	....
87	" 1..	2·00	Coming in	3·3	67	67	1·0220	....	....	....
88	" 2..	2·15	"	3·6	66	66	1·0220	....	....	....
77	" 2..	2·40	"	54	63	62·5	1·0222	1·0218	1·617 1·610	2·916 2·903
89	" 2..	3·15	"	5	65	63·5	1·0221	....	....	....
90	" 2..	3·40	"	27	65	63·5	1·0221	1·0215	1·619 1·623	2·919 2·925
91	" 2.	4·35	High..........	4	66	65·5	1·0220	....	....	....
92	" 2..	4·55	"	3	69	68·5	1·0225	....	....	....
90	" 2..	8·15	Going out......	12·5	64·5	64·5	1·0221	1·0221	....	....
12	" 2..	8·35	"	18·5	65	64·25	1·0219	1·0220	....	....
93	" 2..	8·55	"	2·75	66	66	1·0223	....	1·607	2 8965
94	" 2..	9 10	"	3·3	65	65	1·0224	....	....	....
95	" 2..	9·30	"	3·25	65	65	1·0224	....	1·616	2 913
96	" 2..	10·00	"	20·00	65	65	1·0221	1·0221	1·616 1·616	2·913 2 913
97	" 2..	10·15	"	8	65	65	1·0222	1·0221	....	....
30	" 2..	11·00	Low..........	8	66	66·5	1·0210	1·0217	....	....
98	" 2..	11·30	"	2	68	68	1·0184	....	1·309	2·361
99	" 2..	11·50	"	3·25	66·5	66·5	1·0217	....	....	....
100	" 2..	12·30	Coming in......	3	66	66	1·0211	....	....	....
101	" 2..	12·45	"	2·5	66 5	66·5	1·0217	....	....	....
102	" 2..	1·00	"	4	68	66	1·0221	....	....	....

TABLE of Physical Properties—*Concluded.*

Station.	Date.	Time.	Tide.	Depth.	Temperature top.	Temperature bottom.	Specific Gravity, top.	Specific Gravity bottom.	Chlorine.	Total Solids.
									p. c.	p. c.
103..	Sept. 2..	1·22	"	3	66·75	66·75	1·0217	......	......	......
104..	" 2..	1·45	" ..	2	66	66	1·0210	......	......	......
105..	" 2..	2·00	" ...	3	68	66·75	1·0212	......	......	......
22..	" 2..	2·30	" ...	2	68	67·75	1·0210	......	......	......
106..	" 2..	2·45	" ..	4	68	67	1·0220	......	......	......
51..	" 2..	3·00	" ...	3·5	66·25	66·25	1·0220	......	......	......
107..	" 2..	3·25	"	4	65·25	65·25	1·0221	......	......	......
55..	" 2..	3·40	"	2·5	67·5	67·5	1·0224	......	......	......
108..	" 2..	4·05	"	4	68	66	·1·0220	......	......	......
109.	" 2..	4·10	"	4·25	66	66	1·0222	......	......	......
37.	" 2..	4·30	"	4	68	67·5	1·0222	......	......	......
110..	" 2..	4·50	"	4	69	69	1·0228	......	......	......
111..	" 3..	8·20	Going out	2·5	65·5	65·5	1·0220	......	......	......
112..	" 3.	8·50	" ..	28	64·5	64	1·0222	1·0222	......	......
37..	" 3..	9·05	" ...	5	66	65·5	1·0224	1·0223	......	......
113..	" 3..	9·25	" ...	5	64·5	64	1·0222	......	......	......
114..	" 3..	9·40	"	30	65·25	65	1·0222	1·0220	*1·576* 1·5915	*2·841* 2·870
5..	" 3..	10·00	" ..	12	65·75	67	1·0216	......	......	......
115..	" 3.	10·35	"	4	66	65·75	1·0219	......	......	......
116..	" 3.	10·45	"	3·3	66	66	1·0212	......	1·524	2·747
6..	" 3..	11·05	"	4·25	66·5	65·75	1·0212	......	......	......
117..	" 3.	11·30	Low	3	66	66	1·0218	......	......	......
118..	" 3	12·30	"	3·3	67	66	1·0220	......	......	......
119..	" 3..	12·55	"	3·5	67·5	66·5	1·0228	......	......	......
19..	" 3..	1·20	Coming in....	2·6	67·75	66·5	1·0221	......	......	......
120..	" 3..	1·45	"	2	67	67	1·0223	......	......	......
121..	" 3..	2·20	"	3·3	68·5	68·25	1·0220	......	......	......
50..	" 3..	2·44	"	4·25	66·5	65	1·0220	......	......	......
122..	" 3..	3·35	"	4·5	71	68·5	1·0221	......	......	......
123..	" 3	4·00	"	3	68	67·5	1·0210	......	......	......
124..	" 3..	4·15	"	3·3	67	66·75	1·0214	......	......	......
125..	" 3..	4·45	" ...	2·5	70	70	1·0220	......	......	......
31.	" 3.	4·50	"	3	66	66	1·0216	......	......	......
126..	" 3..	5·05	" ...	3·6	58	68	1·0219	......	......	......

The table shows the salinities of samples of water taken in various parts of the bay, from the surface and also from the bottom. No samples were taken from intermediate depths. The figures show that the densities are well suited to the life and growth of oysters.

During the early part of the summer, samples were obtained from the bottom by means of a narrow-necked bottle wrapped with a sufficient quantity of sheet lead to cause it to sink readily. The bottle was lowered by means of a trawl-line which was securely fastened to both cork and neck of the bottle in such a manner that a short loop of line was left between them. The cork was tightly inserted and the bottle lowered by means of the cork to the desired depth and the cork released by sharply jerking the trawl-line. The bottle now filled was raised to the surface. On July 1 the brass bottle devised by Dr. H. F. Moore was obtained through the Bureau of Fisheries, Washington, U.S.A., and was used after that date.

The specific gravities were taken by means of delicate hydrometers graduated from 1·0000 to 1·0100, from 1·0100 to 1·0200 and from 1·0200 to 1·0300. The readings obtained were reduced to specific gravities at 60°F.

Samples of water from various localities were sent to Professor A. B. Macallum's laboratory at the University of Toronto, Dr. Roger Manning very kindly determined

the percentage of chlorine and the amount of total solids in these. His results are given in the last two columns of the table. In certain cases two sets of results are given. Those in italics are from the bottom.

The temperatures at top and bottom were taken with a Negretti and Zambra reversing thermometer. A few of these temperatures are shown in the table. The temperatures rose until about the first of July. The highest temperature recorded, 77°F., was taken on the 10th of July. A temperature of 60° F. was not recorded until June 20; after July 1, no temperatures of less than 60° F., except on one occasion, that of August 25. Early in the season there were often great differences between the surface and bottom temperatures. These differences became much smaller towards the end of the summer. A difference of 9·5°F. is recorded for a depth of 30 feet on June 23. On some occasions the bottom temperature was higher than that at the surface, e.g. at station 5 on September 3: top, 65°75; bottom, 67°. Owing to the low temperature of early summer the oysters did not spawn until after the first of August. Spatting began about three weeks later, and thus the season was short for the growth of the young oysters. The lateness of spawning must considerably increase the danger of the fry being destroyed by sudden falls in the temperature. The fry of the Malpeque oyster, however, must be quite resistent to such falls of temperature, since spatting occurred even after the sudden drop to 54°F. on the night of August 24.

PLANKTON OYSTER FOOD.

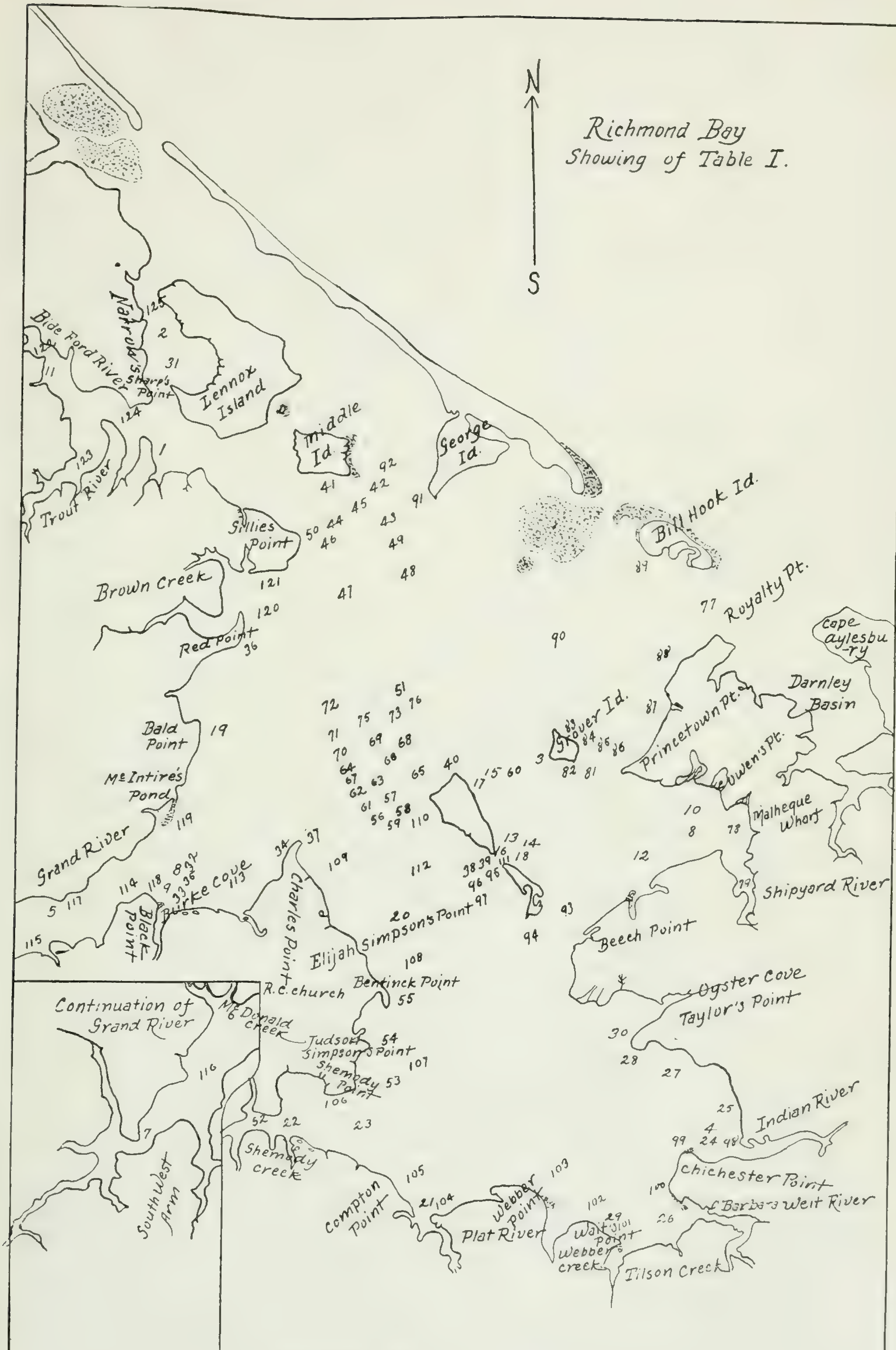
The diatomaceous oyster food collected in various parts of the bay throughout the summer is being worked over by Dr. A. H. MacKay, Superintendent of Education, Halifax, a well-known authority, and his results will be included in a future report.

INFLOW AND AMOUNT OF FRESH WATER.

Arrangements were being made to estimate the inflow of fresh water when it was decided that the desired result was more directly attained by taking the salinities. Fresh water affects the oyster by altering the salinity of the water in which the oyster lives. There are a great number of small streams flowing into Richmond bay. Owing to the fact that the woods are largely cleared away, the water rushes down quickly in the spring, and the volume of many of these streams is greatly augmented at this season while it is inconsiderable during the summer months. Unfortunately, records are not yet available of the densities of the water in the various parts of the bay while these spring floods are on.

PRESENCE OF OYSTER ENEMIES.

Starfish (*Asterias vulgaris* Verrill.) are abundant now in Richmond bay. A few years ago they were a curiosity. They constitute one of the worst enemies of the oyster in this bay. They are found in all parts of it, but are particularly abundant on the oyster grounds around the Curtain islands and in the Big bay. The government oyster steamer, the *Ostrea,* under Captain Kemp, the Dominion oyster expert, did good work during the summer, cleaning out starfish on the beds to the west of Curtain island and in the Big bay. He was assisted during the month of June by government patrol boats *D* and *E*. Some of the oyster companies also did service in this line. Both government and oyster companies should pursue this line of work much more vigourously, and the good results attained should be conserved and not lost as they were to a great extent last summer. The starfish fished from the beds are removed from the bay of course, but in the case of the work done by the *Ostrea* there was an indirect but none the less important result which was not conserved. The bed effectively cleared of starfish was swept by the starfish-mops and left white and clean and in good condition to secure a set of spat, had it not been torn to pieces by oyster-planters dredging for shell. This shell might have been secured from other beds not cleaned in this way.


Richmond Bay
Showing of Table I.
N
S
Lennox Island
Middle Id.
George Id.
Bill Hook Id.
Royalty Pt.
Darnley Basin
Princetown Pt.
Owen's Pt.
Malheque Wharf
Shipyard River
Grover Id.
Beech Point
Oyster Cove
Taylor's Point
Indian River
Chichester Point
Tilson Creek
Webber creek
Wait Point
Webber Point
Plat River
Compton Point
Shemody creek
Shemody Point
Judson Simpson's Point
McDonald creek
R.C. church
Bentinck Point
Elijah Simpson's Point
Charles Point
Burke Cove
Black Point
Grand River
McIntire's Pond
Bald Point
Red Point
Brown Creek
Gillies Point
Trout River
Bide Ford River
Narrows
Sharp's Point
Continuation of Grand River
South West Arm

Large starfish were obtained in the dredge from the beds in the deep water and great numbers of young starfish were found in certain parts of the eel-grass-covered sand areas. Many of the fishermen are not yet convinced of the fact that a starfish torn in two and thrown back into the water grows into two starfish.

A boring sponge (*Cliona celata* Grant), for the identification of which the writer is indebted to Lawrence M. Lambe, F.G.S., occurs on some of the beds, more particularly in the mud areas. Fortunately one finds only a small percentage of shells attacked. This sponge, however, does considerable damage to the oysters which it attacks. Although it may not kill the oyster it weakens it by forcing it to expend its energy in repairing the shell, which is almost honeycombed by the sponge. The weakened shell leaves the oyster a much easier prey to its other enemies.

The drill (*Urosalpinx cinera* Say) is not known to occur in Richmond bay, although there is a small borer (*Tritia trivittata* Adams) which does penetrate the soft shells of *Pandora trilineata* Say, and which may possibly do damage to small oysters. It is very abundant in some parts of the bay.

The slipper limpet (*Crepidula fornicata* Lamarck) is very abundant and must come into competition with the oyster for points of attachment and for food. *Crepidula plana* Say, also occurs.

Eel-grass (*Zostera marina* L.) renders areas unfit for planting oysters until it is cleared off, smothers oysters when it is dead by lodging on them, and interferes with the setting of oyster spat, as will be pointed out in the account of the experiments on spatting. Certain seaweeds also grow on the rocks and interfere with the setting of spat here.

Ice, it is stated, destroys many young oysters on such points as those to the north of Grover and Bunbury islands. Many of these would doubtless be saved were these points leased. If leased to fishermen they could carry on operations here without the outlay of much capital. Clean cultch could be distributed over these points in retainers such as those used in our spat-collecting experiments, and these could be lifted and sold to the oyster companies before the ice formed in the autumn.

No doubt some oysters are destroyed by sifting sand, but it does not yet appear that the loss from this source is very great.

Sudden falls of temperatures such as that on the night of August 24 no doubt destroy great numbers of the oyster fry. That even such great drops as this do not destroy all is shown by the fact that spat set in several places after that date.

The most destructive enemy the oyster has, however, is man. Oyster poaching goes on widely, but were the oyster poacher and the man who buys from him severely dealt with, and efficient protective legislation effectively and impartially enforced, there would be a great advance in the oyster industry in Richmond bay.

OCCURRENCE OF SMALL OYSTERS AS EVIDENCE OF SPATTING.

The small number of young oysters shows either that spatting has not been good in recent years or that there has been a high death-rate among the small oysters. There is almost always, however, a good or at least a fair "set" in a few places such as the north point of Grover island, on the Curtain Island shoals, and in the narrows between Curtain island and the mainland. There is also generally a fair set in the Grand river and often near the mouths of the Indian and Barbara Weit rivers at the south end of the Big bay. There was a very light set in 1913. A few 1-year-old oysters occur at Grover island, in the narrows, and near the mouth of the Barbara Weit river. Two-year-old oysters were more abundant and more widely distributed. Small oysters up to 3 or 4 years old were found in the narrows, on the rocky shoals near George island, the rocky points north of Grover and Bunbury islands, the Grand river and at various points in the Big bay. Spatting does take place, and there is no doubt in the writer's mind that it would take place more abundantly if precautions were

taken to secure the protection of the old beds and to provide suitable cultch for spatting. A few years ago, when the channel to Malpeque wharf was dredged, the material removed, among which was a quantity of old shell, was dumped on what is now known as the "old dump." This shell, partially cleaned in the process, served as cultch for a set of spat and the "old dump" is to-day, as far as an overfished bed can be, a good bed.

OCCURRENCE OF DEAD OYSTER SHELLS AS EVIDENCE OF FORMER PRODUCTION.

There are extensive and deep old shell beds all over the Big bay and in many places in the Inner and Outer bays as well. These beds consist in the main of old oyster and quahaug shells, with a smaller proportion of live oysters and quahaugs. These beds occur not only in the main portions of the bay but in the rivers as well. Beds are found in the Grand, Bideford, Trout, Barbara Weit, and Indian rivers, and also in Shemody creek.

An attempt was made to obtain measurements of the thickness of some of these old beds. This can be satisfactorily done only by boring, and boring can best be done through the ice in winter. A rough estimate of the thickness was made by poling across the beds and through the mud at the sides. The sounding over the summit, which usually lies near one edge, was subtracted from that through the mud at the side and the difference taken as the depth of the bed. This estimate is admittedly only an approximation, but it is believed to give a fair idea of the depth. The following are the estimates for some of the beds:—

1. September 2.—Little Curtain Island bed—
   Off the north side—
      Top, 7·5 feet; bottom, 24 feet; thickness, 16·5 feet.
   Off the south side—
      Top, 8 feet; bottom, 22 + 6 = 28 feet; thickness, 20 feet.
2. September 3.—Bell bed, Grand river—
   Top, 6 feet; bottom, 10 + 7 = 17 feet; thickness, 11 feet.
3. September 3.—Bed above the ferry, Grand river—
   Top, 12 feet; bottom, 12 + 6 = 18 feet; thickness, 6 feet.
4. September 12.—Bed northwest of Bunbury island—
   Top, $10\frac{1}{4}$ feet; bottom, $19\frac{1}{2} + 5\frac{3}{4} = 25\frac{1}{4}$ feet; thickness, 15 feet.
5. September 12.—Little Curtain Island bed—
   Off north side—
      Top, 7·5 feet; bottom, 21·5 + 3·5 = 25 feet; thickness, 17·5 feet.
   Off south side—
      Top, 7·5 feet; bottom, 26 + 5·5 = 31·5 feet; thickness, 24 feet.
6. September 12.—Little Curtain Island bed, west end—
   Top, 7·25 feet; bottom, 21·5 + 6 = 27·5 feet; thickness, 20·25 feet.
7. September 12.—Bed middle of Big bay, west of Curtain island—
   Top, 10 feet; bottom, 22·5 + 7·5 = 30 feet; thickness, 20 feet.
8. Chinick bed—
   Top, 16 feet; bottom, 21·5 + 7·5 = 29 feet; thickness, 13 feet.

The differences between the measurements of the depth of the Little Curtain Island bed are to be explained by the fact that the bed is a large one, and the measurements were not made in the same places on the two dates.

The mud-diggers take shell from considerable depths. The writer was informed that the face of the cut, which is all shell-bearing, is sometimes 24 feet in height. These points all indicate the oyster has existed in Richmond bay for a very great number of years. Throughout this period the conditions must have been favourable for oyster life. The presence of so much shell in the water insures a supply of lime for shell development in the live oysters.

FREEZING TO BOTTOM IN WINTER.

Young oysters are said to have a high death-rate on the north point of Grover island. This would appear to be due more to crushing by the ice than to freezing, since many oysters survive in the depressions, in the small crevices, and on the sides of stones. No evidence was obtained that oysters were killed on the beds by freezing. It was commonly stated that the ice was thin over the beds and that the thinness was a source of danger to travellers on the winter roads across the bay unless these roads avoided the beds. Some attributed it to the "natural heat" of the oyster beds. Others more properly to the currents which are naturally stronger over the shallow beds.

TIME OF SPAWNING.

Spawning was late this year. Oysters began to shed their spawn and oyster fry to appear in the water about the first of August. Fry was still found in the bay on the 29th of August, but none after that date. The oysters in the warmer water spawned somewhat later than those in the cooler water, there being a difference of about two or three days in the date of spawning at the south end of the Big bay and that in the Inner bay, and the deep-water oysters retained their spawn about a week after those in the shallower beds and in the rivers had shed all theirs. The bulk of the spawning took place during the first three weeks of August.

TIME AND EXTENT OF SPATTING.

Spat-collectors were made by placing shell in cylindrical containers made of wire netting. These, which were from 2 to 4 feet in height, were placed at various points around the bay. They were kept upright by being firmly wired to stakes. They were numbered, and at the end of the season were removed to deeper water to permit of further observations during subsequent seasons. The attempt to secure spat by the use of glass strips, placed with each collector, proved unsuccessful.

The following account shows in respect to each collector: the date set out, the location, some account of the environmental factors, the date taken up, the set of spat, and some account of the condition of the shell at the time of lifting.

1. August 19.—Bideford river, end of the first point above the wharf; near but not in eel-grass; oyster beds farther up the river; September 14, set heavy; heavily slimed over.

2. August 19.—Trout river, lowest point on the left bank; in 3·5 feet, near but not in eel-grass; oyster beds close at hand; September 14, set heavy; heavily slimed over.

3. August 19.—Bideford river, left bank, Sharp's point; in 3·5 feet on edge of eel-grass; near oyster bed; September 14; set heavy; heavily slimed over.

4. August 19.—Narrows between Lennox island and the mainland, Sharp's bed "Rock bed"; in 2·5 feet, no eel-grass on oyster bed; September 14; set heavy; heavily slimed.

5. August 19.—Narrows between Lennox island and the mainland, Sharp's bed (Peter Creek bed); in 2·5 feet, no eel-grass on oyster bed; September 14; set heavy; heavily slimed.

6. August 19.—Lennox island, first point northwest of the wharf; in 4 feet, among eel-grass, not close to oyster beds; September 14, no set, moderately slimed. (This collector fell over shortly after being set out and was left lying).

7. August 19.—Gillies point; in 2·5 feet, among eel-grass, not close to oyster bed; September 14; set light; slightly slimed.

8. August 20.—Middle island, southwest point; in 3 feet, among eel-grass, not close to oyster beds; September 14; no set; slightly slimed.

9. August 20.—Middle island, southeast point; in 3 feet, among eel-grass, near scattered oysters; September 14, set light; slightly slimed.

10. August 20.—George island, west of south point; in 4 feet, among eel-grass, near scattered oysters; September 14, no set; slightly slimed.

11. August 20.—George island, west of shoal running out from south point, about half-way out on shoal; in 3 feet, among eel-grass, near rock oysters; collector lost.

12. August 20.—George island, end of the shoal running out from south point; in 4 feet, among eel-grass, near rock oysters; collector lost.

13. August 20.—Bill Hook island, end of shoals to the southwest; in 7 feet, among eel-grass, not near oysters; September 14, no set; slightly slimed.

14. August 20.—Bill Hook island, shoals near lighthouse; in 7 feet, among eel-grass, not near oysters; September 14, no set; slightly slimed.

15. August 21.—Shipyard river, left bank, point above Crafer's; in 2 feet, on edge of eel-grass, just above oyster bed; September 16, set fair; slightly slimed.

16. August 21.—Shipyard river, right bank, Crafer's point; in 2 feet, on edge of eel-grass, just below oyster bed; September 16; set fair; slightly slimed.

17. August 21.—Shipyard river, channel above wharf; in 2·5 feet, no eel-grass, on oyster bed; September 16, set fair; slightly slimed.

18. August 21.—Shipyard river, left bank, Ramsey's point; in 3 feet, among eel-grass, not far from oyster beds; September 16; set fair; slightly slimed.

19. August 21.—Shipyard river, Owen's point end of point; in 2·5 feet, among eel-grass, not far from oysters; September 15, set fair; slightly slimed.

20. August 21.—Shipyard river, Owen's point, west of point; in 2·5 feet, on edge of eel-grass, not far from oysters; September 15, set fair; slightly slimed.

21. August 21.—Inner bay, Ellison's point; in 2·5 feet, on edge of eel-grass, not far from oysters; September 15, set fair; slightly slimed.

22. August 21.—Shoals between Princetown point and Grover island, middle of south side; in 2·5 feet among eel-grass, not far from oysters; September 15, set fair; slightly slimed.

23. August 21.—Grover island, middle of the northeast side; in 2·5 feet; among eel-grass, not far from oysters; September 14, set fair; slightly slimed.

24. August 21.—Grover island, off northeast point; in 2·5 feet, among eel-grass, not far from oysters; September 14, set fair; slightly slimed.

25. August 21.—Shoals between Princetown point and Grover island, middle of north side; in 2·5 feet, among eel-grass, not far from oysters; September 14, set fair; slightly slimed.

26. August 21.—Outer bay, shore between Princetown and Royalty points, Montgomery's point; in 2·5 feet, among eel-grass, not far from oysters; collector lost.

27. August 21.—Outer bay, shore between Princetown and Royalty points, point first west of Royalty; in 2·5 feet, on edge of eel-grass, not far from oysters; September 14; set fair; slightly slimed.

28. August 21.—Outer bay, north of Princetown point; in 2·5 feet, among eel-grass, not far from oysters; September 14, set light; slightly slimed.

29. August 21.—Grover island, north point; in 2 feet, on rocks, among very short seaweed, among rock oysters; September 15, set heavy, heavily slimed.

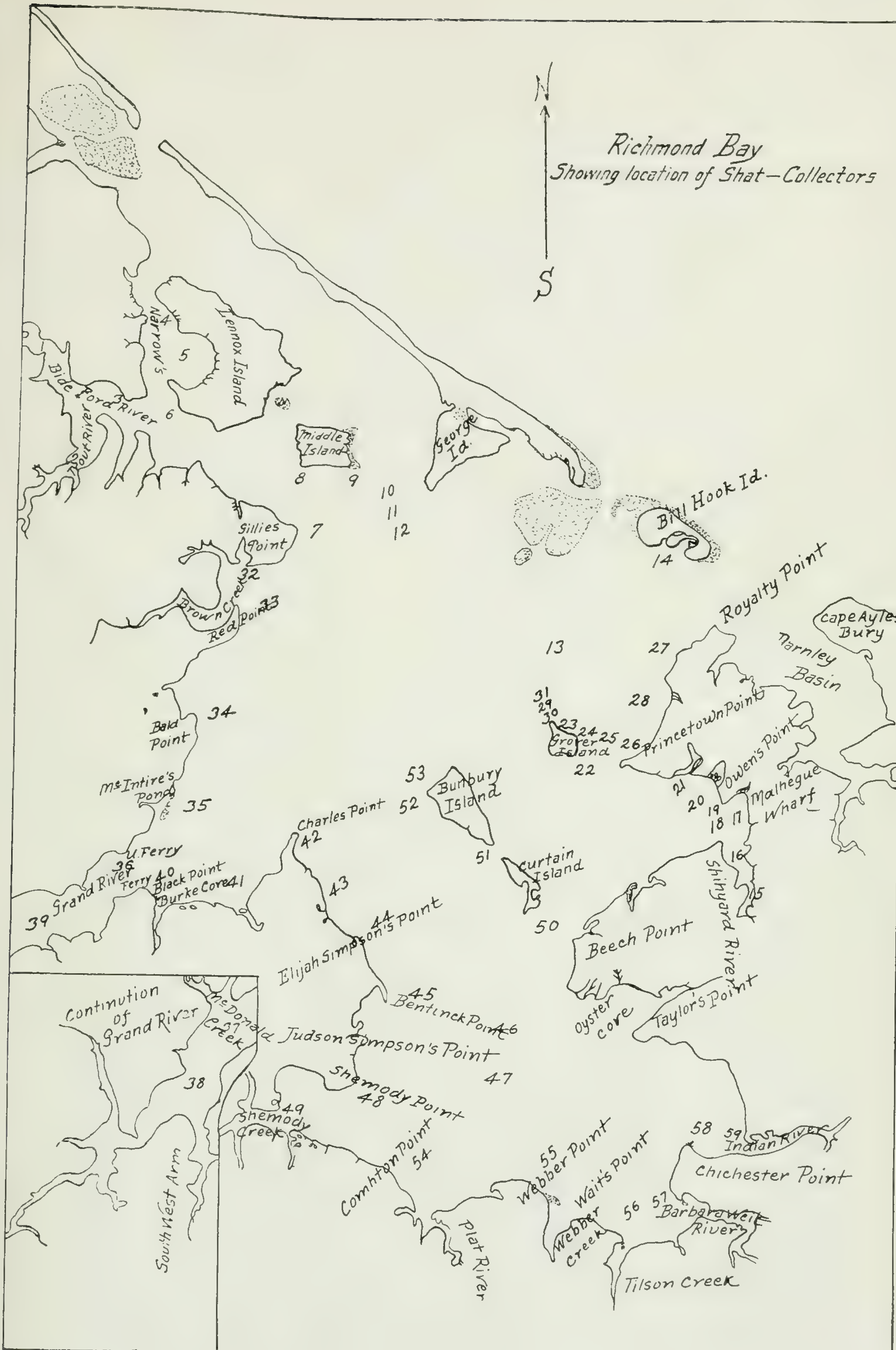
30. August 21.—Grover island, north point; in 1·5 feet, on rocks among short seaweed, among rock oysters; September 15, set heavy; heavily slimed.

31. August 21.—Grover island, north point; in 2·5 feet, on rocks among short seaweed, among rock oysters; September 15, set heavy; heavily slimed.

32. August 24.—Point west of Gillies point, mouth of Brown creek; in 2 feet, on edge of eel-grass, not near oysters; September 16; set light; slightly slimed.

33. August 24.—Red point; in 3·5 feet, among eel-grass, not near oysters; collector lost.

34. August 24.—Bald point, in 2·5 feet, among eel-grass, not far from oysters; September 16; set light; slightly slimed.


Richmond Bay
Showing location of Shat—Collectors
N
S
Lennox Island
Narrows
Bide Ford River
Trout River
Middle Island
George Id.
Bill Hook Id.
Sillies Point
Brown Creek
Red Point
Bald Point
McIntire's Pond
U. Ferry
Grand River
Ferry
Black Point
Burke Cove
Charles Point
Bunbury Island
Curtain Island
Elijah Simpson's Point
Royalty Point
Cape Aylesbury
Darnley Basin
Princetown Point
Grover Island
Owen's Point
Malhegue Wharf
Shipyard River
Beech Point
Oyster Cove
Taylor's Point
Bentinck Point
Judson Simpson's Point
Shemody Point
Shemody Creek
McDonald Creek
Continuation of Grand River
South West Arm
Compton Point
Webber Point
Wait's Point
Webber Creek
Plat River
Indian River
Chichester Point
Barbara Weit River
Tilson Creek

35. August 24.—Near McIntyre's pond; in 3·5 feet, among eel-grass, not near oysters; September 16; set light; slightly slimed.

36. August 24.—Grand river, Bell's point; in 3 feet, no eel-grass, close to oyster bed; September 16; set light; heavily slimed.

37. August 24.—Grand river, mouth of Macdonald creek; in 4 feet, on rocky bottom near eel-grass, not far from oyster beds; September 16; set heavy; moderately slimed.

38. August 24.—Grand river, point opposite Southwest arm; in 3·5 feet, among eel-grass, near oysters; September 16; set fair; moderately slimed.

39. August 24.—Grand river, point right shore above ferry; in 4 feet, among eel-grass, near oysters; September 16; set light; slightly slimed.

40. August 24.—Grand river, Black point; in 3·5 feet, among eel-grass, not far from oysters; collector lost.

41. August 24.—Half-way between Black and Charles points; in 5 feet, among eel-grass, not near oysters; September 16; no set; slightly slimed.

42. August 24.—Charles point; in 4 feet, no eel-grass, near oysters; September 15; set light; slightly slimed.

43. August 24.—South of Charles point, half-way to Simpson's point; in 4·5 feet, among eel-grass, not far from oysters; September 15; set light; slightly slimed.

44. August 24.—Between Charles and Bentinck points, Simpson's point; in 4 feet among eel-grass; not far from oysters; September 15; set light; slightly slimed.

45. August 27.—Bentinck point; in 2·5 feet, among eel-grass, not far from oysters; September 15; set light; slightly slimed.

46. August 27.—Bentinck shoal, north side; in 4 feet, among eel-grass not far from oysters; September 15; set light; slightly slimed.

47. August 27.—Bentinck shoal, south side; in 3·5 feet, among eel-grass, not far from oysters; September 15; set light; slightly slimed.

48. August 27.—Shemody point; in 4 feet, among eel-grass, not far from oysters; September 15; set light; slightly slimed.

49. August 27.—Shemody creek; in 2 feet, among eel-grass, near oysters; September 15; set light; slightly slimed.

50. August 27.—Curtain Island shoals, west side between Beech point and Curtain island; in 3·5 feet, in clear patch among eel-grass, near oysters; September 15; set heavy; slightly slimed.

51. August 27.—Curtain island shoals, west side, between Curtain and Bunbury islands; in 3·5 feet, among eel-grass, near oysters; September 15; set light; slightly slimed.

52. August 27.—Curtain Island shoals, west side of Bunbury; in 4 feet, among eel-grass, near oysters; September 15; set light; slightly slimed.

53. August 27.—Curtain Island shoals, northwest of Bunbury; in 5 feet, among eel-grass, not far from oysters; September 15; set light; slightly slimed.

54. August 28.—Plat river, Compton's point; in 2·5 feet among eel-grass, not far from oysters; September 15; set light; slightly slimed.

55. August 28.—Webber point; in 3 feet, among eel-grass, not far from oysters; September 15; set light; slightly slimed.

56. August 28.—Barbara Weit river, near Wait's point; in 2·5 feet, among eel-grass, not far from oysters; September 15; no set; slightly slimed.

57. August 28.—Barbara Weit river, west of Mill's point; in 3 feet, among eel-grass, near oysters; September 15; set light; slightly slimed.

58. August 28.—Indian river, east of Chichester point; in 3·5 feet, on edge of eel-grass, near oysters; September 15; set light; slightly slimed.

59. August 28.—Indian river, point at mouth right bank; in 2 feet, among eel-grass, near oysters; September 15; set light; slightly slimed.

60. August 28.—Grover island, north point; in 2 feet, on rocks, among short seaweed, among rock oysters; September 15; set light; moderately slimed.

61. August 28.—Grover island, north point; in 2 feet, on rocks, among short seaweed, among rock oysters; September 15; set light; moderately slimed.

Collectors 1 to 60 were filled with shell picked from oyster-mud, while collector 61 was filled with fresh oyster-shell. Collectors 60 and 61 were placed together in order to test the relative efficiency of fresh and old shell. No difference was observable but, owing to the fact that fresh shell was not obtained before August 28th these collectors were too late in being placed out to make the test a conclusive one.

The tests show that spat sets in practically all parts of the bay, wherever there is suitable cultch material. The set was in general light, although in a few places it was good. The result would, without doubt, have been very much better had it been possible to set out the collectors earlier. The set was best in locations where the water was shallow, easily warmed, and where the bottom, free from eel-grass, was swept by currents from oyster beds not too far distant. The whole investigation leaves the impression that of late years the set of spat has suffered a great decrease. Set of spat is a thing essential to oyster production in Richmond bay, and it would seem advisable to institute a strictly close season until spatting has again reached normal proportions. The attempt to restock the bay by means of American oysters would probably meet with very indifferent success. Even were it demonstrated that they would flourish and grow, there remains the much more doubtful question as to whether they would reproduce themselves or not. Besides, Malpeque oysters have a name which it is good policy to retain. There would, moreover, be the serious danger of introducing the devasting drill along with the oysters.

FORMER OUTPUT OF THE BAY.

The following statement of the number of barrels of oysters shipped from Prince Edward Island through the Charlottetown Steam Navigation Company will give some idea of the relative proportions of the oyster trade from Richmond bay through a series of years subsequent to 1889. The writer is indebted to the kindness of the company for it. Other companies have handled oysters, but information could not be obtained concerning the amounts. All the oysters handled by the Charlottetown Steam Navigation Company were not Richmond Bay oysters, but the bulk of them were. The statement will give a very fair idea of the relative trade from year to year in respect to the oysters from this bay.

	Barrels.		Barrels.
1889	23,538	1902	17,271
1890	20,033	1903	14,916
1891	20,825	1904	12,280
1892	23,654	1905	12,406
1893	20,328	1906	12,283
1894	15,565	1907	7,456
1895	15,265	1908	7,472
1896	15,157	1909	9,190
1897	12,661	1910	7,196
1898	16,550	1911	7,589
1899	15,161	1912	6,908
1900	15,683	1913	12,982
1901	18,238		

The sudden rise in the number of barrels shipped in the year 1913 is eloquent in support of the contention that there should be a strictly enforced close season. It was ten years since there had been so heavy a shipment of oysters. The figures show that the oyster trade was of considerable importance twenty-five years ago and that it has dwindled in that period until it was in 1912 less than one-third of its extent at the beginning of the period. The need of protection is very apparent.

CONCLUSIONS.

1. The character of the bottom is favourable to the development of oysters. There is a considerable amount of mud bottom, but there are also extensive tracts of good hard clean bottom on which it should be possible to develop good oyster areas.

2. Eel-grass is abundant throughout the shallow areas, and will demand the expenditure of labour and money in order that it may be kept in check.

3. The salinity of the water, although somewhat high, is still favourable to the production of oysters and, judging by the oysters seen during the summer, of very fine quality.

4. The temperatures are somewhat low until rather late in the summer. In this way the spatting is delayed and the season of growth during the same season shortened. The low temperature probably does decrease the rate of growth of and the number of oysters in Richmond bay, but it would appear that it improves their quality.

5. Although the identification of the diatoms, kindly undertaken by Dr. A. H. MacKay, is not yet completed, it may be here stated that there is an abundant supply of oyster food in the waters of this bay.

6. The enemies of the oyster are not yet a serious menace in Richmond bay if proper measures are taken to keep them in check. The most serious depredations are those made by man and the starfish.

7. Spatting falls short of the requirements for successful oyster growing, but this condition of affairs may be remedied.

8. Oysters have existed in Richmond bay for a very great number of years, and have been much more plentiful in former years than they are at present. This would appear to be due to overfishing.

The oyster beds of Richmond bay are in bad shape, but their condition may be remedied. There is no evidence on which one can make the statement that natural conditions bar the development of oyster production. Eel-grass and starfish present difficulties which may be successfully contended with. No good evidence was obtained that the physical conditions are more unfavourable than they have been in the past. The chief danger to oyster production is disregard for and slack enforcement of the law. The hope for the regeneration of the oyster industry as a great national asset lies in a strict and impartial enforcement of protective regulations.

RECOMMENDATIONS.

The writer would favour the following steps as most desirable:—

1. That measures be taken to more rigidly enforce the oyster laws.

2. That a close season of at least three years be established, during which no one be permitted to take oysters from the public beds, and during which the sale of oysters taken from any bed, public or private, in the bay be prohibited.

3. That the ground between the 4-foot line and the shore be leasable to the fishermen for spatting grounds.

VI.

A SUPPOSED DISEASE OF QUAHAUGS FROM NEW BRUNSWICK.

By Philip Cox, Ph. D., *University of New Brunswick.*

The Quahaugs, supposed to suffer from some affection or disease, were from Buctouche, N.B., and were studied chiefly at the Biological Station, St. Andrews, in 1914. Buctouche, Kent county, is situated on the estuary of the Buctouche river, there about 200 feet wide, with an average depth of 20 feet at low water. The population is about 600. The town is not incorporated, but has a board of health which does not allow waste nor objectionable matter to be dumped into the stream nor on the ice in winter. There is no sewerage system, and only two or three private drains enter the river, hence no pollution of the water seems possible in a stream of its volume with a rise and fall of tide of from 2½ to 4 feet.

Above the town there are extensive marshes, overgrown with weeds and grass, and laid bare generally at low water, and hence much decaying organic matter is swept seaward, rendering the stream quite turbid. The temperature of the flow is apt to run high, for the water, spread out for hours over the marshy flats, has had time to become warmed, especially during midsummer when from 68° to 70° F. cannot be unusual; indeed, when tested at 3 p.m. on July 24, it stood at 70°. Owing to the quantity of fresh water entering the estuary from the upper river and its branches, the salinity is apt to be low, especially at low water and during the spring and early summer when the fresh water is at its maximum.

MANNER OF STORING.

The hard-shell clams or quahaugs are confined in floating trays 18 feet by 14 feet by 18 inches, made of boards from 4 inches to 6 inches wide with ½-inch spaces, and moored end to end along the shore in several tiers or ranges. This close arrangement, and the very narrow slots, often overgrown and clogged with algæ, are not favourable to a rapid change of water; indeed the force of the tide either way as a factor aiding the change can be barely perceptible beyond the second tray tidewards, and although a slow interchange is always going on, it must be entirely inadequate to the vital needs of such an immense number of shell-fish crowded together in the manner described. An unobstructed flow of water is still more required to offset the injurious effects of the low salinity and high temperature to which they are exposed, often for several months before shipment. This prolonged period of confinement under abnormal conditions must sap the vitality of the animal and render it less resistant to the still more unnatural and trying conditions of transportation and marketing, particularly if the quahaugs were taken from the beds in May before they had recruited after a long winter of inactivity.

The trays are usually filled to the depth of from 6 inches to 15 inches, but when arrivals from the fishing grounds are large, and space limited, they are filled to their utmost capacity and readjusted as soon as extra space is available. Three or four days after, they are turned, if the trays are up to their full capacity, with forks of 8 or 9 tines with chisel points, and broken or dead ones are thrown out; but no close examination is made; whatever happens to be seen is rejected, and, as a matter of fact, dead clams and broken shells were more or less in evidence. It was noticed, moreover, that the middle trays—those farthest removed from the effects of the tide either way—contained the most dead quahaugs, which fact may be regarded as a result, at least

partially, of the very poor water circulation. How often they are turned depends on circumstances; but, as a considerable growth of algæ and much sediment was seen in some of the trays which had not been recently disturbed, probably once a week would be the maximum. The trays are said to be scrubbed and dried at intervals, and one was seen undergoing the process. It was pointed out that the fork with its chisel-pointed tines, used in turning the clams, may do more or less damage to the mantle, protruding siphons, or edges of the valves, but a close inspection of the material sent to the station for study does not bear out this view, though chipped valves were found in a few cases.

MATERIAL AND ITS SOURCES.

The clams thus stored are of one species, *Venus mercenaria* L., the short-necked or round clam, or quahaug. It occurs on the gulf shores of New Brunswick and Prince Edward Island, chiefly on mixed sand and clay bottoms and at the level of 1 to 5 fathoms below low tide, but its distribution is local, not general, determined by bottom conditions and influences not understood. Though common on some parts of the New England coast south of cape Cod, it does not seem to occur in the Bay of Fundy nor on the Atlantic coast of Nova Scotia, excluded therefrom doubtless by the colder Arctic waters.

The fishery begins in May, extends to the end of June, and reopens in September, the two intervening months, it is believed, covering the period of spawning; but much remains yet to be learned, not only as regards the length of the reproductive season, but of those occult influences which determine the peculiar distribution of the bivalve. All its known beds are for many months covered, more or less, with ice, the temperature falls, and the clam buries itself in the muds, ceases to feed, and necessarily falls off in condition. Just when it emerges from this dormant state and begins to feed is not definitely known, but is supposed to be about the first of May; yet much must depend on weather conditions and the time the ice disappears, for some springs, like that of 1914, are colder and later than usual. Those clams raked in May, then, are likely to be inferior in quality, to be lacking in the vigour and the vitality of later catches, especially those of October, and are not likely to stand storage and shipping conditions as well. The transfer from cold sea-water of average salinity to the warmer river estuary, fresher at that time than at any other time of the year, perhaps, must tax the animal's powers of resistance to a dangerous degree. It would seem that the early May catch is the largest of the season, for the more remunerative salmon and lobster fisheries are then scarcely under way, and many fishermen are free to rake the clam beds for a time. These large May receipts are stored and kept under the conditions described for some weeks, in some cases two months; and it is somewhat suggestive that most of the shipments to Chicago and New York going bad were either all May fish or were made up in part of that catch. It might be fruitful of good results to this fishery if this were made the subject of a special inquiry. It must be borne in mind, too, that preparation for reproduction and the process itself tax the vigour and vitality of the animal; and development of the generative organs and their elements to a healthy, ripe stage, may depend on recuperation after the trying season of dormancy. Before this is possible, however, the clams are raked, confined, and the natural food supply cut off; an arrest of growth and functional activity ensue, which may seriously affect the health of the clam.

The stock shipped from Buctouche is obtained from beds in the vicinity; from Cocagne, 12 or 15 miles distant; and from Percival and Gulf bays, Prince Edward Island. It is conveyed to the storage grounds in small vessels, the clams being in bags, piled up in the holds or on deck, and from two to four days are required for the passage from the farthest points.

MANNER OF SHIPPING AND EXTENT OF INDUSTRY.

Formerly the clams were shipped in ordinary grain and feed bags, but, a considerable loss resulting, it was thought well to use a more open sack permitting of freer circulation, and the coarse open "coffee" bag of about 1½ bushels' capacity is now in vogue. The quahaugs are sorted and classified as large and small, the soundness is, in one establishment, decided by rapping them together, a manner of testing regarded as injurious by the other, which claims that they are killed by even a slight blow. The action does seem a rather violent one, and it is still a matter of doubt if the jar to a creature of such delicate internal structure and loose arrangement of organs and parts does not produce strains and even ruptures more or less fatal, though the firm objecting to it had also consignments to New York and Chicago go bad. The experiments performed at the station and referred to below are certainly not conclusive on the point.

The sacks of clams are placed in tiers, one on top of the other, the box-car is iced at either end, and re-iced whenever necessary during transit, but no provision is made for the ventilation of the sealed car. The temperature at which it is kept could not be ascertained, nor whether it was uniform; but it is fair to assume that clams taken from water at a temperature of from 68° to 70° F., stored for a week or more in one at from 45° to 50° F., or perhaps less, and then exposed to a temperature of 80° or upwards at their point of destination, must suffer from such extremes; and, if shipped in a weak and physically reduced condition, many may be expected to die. It will be seen that the experiments made at the station are decisive on this point.

The want of ventilation referred to and the pressure at which half or more of the clams are subjected, keeping the valves firmly shut and rendering oxygen utilization nigh impossible, were thought to be important factors; but, in the light of the tests described below, the latter does not seem to be of any importance, at least within the time limits of the experiments, but the former, a condition that should not be ignored.

Two firms, R. O'Leary and Irving & Son, send annually from Buctouche to the American market, chiefly to Chicago and New York, between 600 and 700 tons, or about two carloads per week, from early in May till the middle of November.

Though there is always a loss, it never assumed the alarming proportions it did this summer, as the following record of shipments to Chicago made by Mr. O'Leary show:—

Date of Shipment.	Quantity.	Date of Arrival.	Loss.	Per cent Loss.	Per cent Total Loss.	Max. Temp. Chicago 24 hours, before and after date of arrival.
June 10th...	65,000 large....	June 16.....	14,600 large..	22½	35	70° F.
	33,000 small....		19,800 small..	60		
" 16th...	63,000 large...	" 23.....	22,500 large...	36	29	91° F.
	26,000 small....		3,450 small..	13		
July 1st....	65,000 large....	July 7.....	8,500 large...	13	10	84° F.
	20,000 small....		....			
" 8th....	65,000 large.....	" 13.....	14,000 large...	21½	17½	93° F.
	15,000 small....		....			

The loss in subsequent shipments was unimportant.

It is seen: (*a*) that the large clams generally suffered the more; (*b*) that the small ones were practically immune after June 16, but the large clams continued to die for a month longer; (*c*) that other factors than exposure to high temperature at the point of destination were at work, since the cargo arriving June 16 lost more at a temperature of 70° F., with a mean of 59° for the 15th, 16th, and 17th, than that of July 13 at a temperature of 93° F., with a mean of 80° F. for the 12th, 13th, and 14th, though the death-rate of the large was about the same in both.

The consignees reported the stock diseased, and eventually refused to accept any further consignments, though later on shipping was resumed. The merchants were alarmed, as it meant a big loss and the probable ruin of a growing industry of considerable economic importance, and requested the biological board to investigate the matter. Directed by Professor A. B. Macallum, Toronto University, secretary-treasurer of the board, I went to Buctouche, inspected storage and other conditions, and brought away samples of water and lots of clams from several trays for study at the Marine Biological Station at St. Andrews, which were later supplemented by a special lot from one of the firms. They were all transferred to wooden tanks of sea-water, away from direct light, and jets were kept constantly running to renew and aerate it.

It must be noted that the salinity of this water is greater than that of the mooring grounds at Buctouche, where at low tide the specific gravity was only 1·0178 and at high tide 1·0202, but at the station it registers 1·02425, which was maintained fairly constant throughout, for the reservoirs supplying the tanks are always refilled at high tide. No ill-effects, however, were perceptible during the three or four weeks the bulk of the stock were thus under observation, which implies that the quahaug possesses a considerable power of resistance to osmotic pressure.

EXAMINATION AND TESTS.

An extended microscopic examination of the fluids and organs of many was made, but no trace of disease, due to pathological causes, could be found; a finding accentuated by the fact of only one death occurring among the several hundreds kept in the trays. It died the day after its arrival at the station.

It was conjectured, however, that the series of rather sudden changes of temperature from the storage trays at 70° F. to a sealed box-car at 45° or 50° for a week* or more followed by 80° or 90° F. at the point of destination, might cause a high death-rate of clams kept long in confinement and raked while they were in a reduced condition. To test this, a set of eight were put in the station ice-house for three days in a temperature ranging from 45° to 48°, and were then exposed to the open air at a mean of 60°, the maximum (one instance) being 72°. At the end of three days all were dead but one, which on dissection showed very feeble signs of life.

Another lot of ten was taken directly from the trays and exposed for fourteen days in the open air. They were all alive at the end of that time, and were returned to the trays where they still live, August 25.

These experiments seem to confirm the suspicion that sudden alterations of temperature are fatal. It will be seen, too, that in some respects the test was not so severe as the actual shipping. The ice-house is well ventilated; the duration of exposure therein was three days, not seven; and the average and maximum temperature of the weather was less than in Chicago when the last three shipments arrived. The contrast, however, is great—the first lot all died, the second, exposed longer, survived the test. The maintenance of a uniform average temperature during transit and marketing seems all-important.

A lot of ten were 'rapped" and exposed for six or seven days, and two died after being returned to the water. Of the eight mentioned above, which were subjected to a low temperature in the ice-house, four had been previously "rapped." While the data, then, are too meagre and uncertain to warrant any general conclusion as to the effects of this means of testing the soundness of clams, some considerations seem to point to it being injurious, and hence it should, if possible, be eliminated.

A general falling-off in weight resulted from all exposures. A lot of ten, wiped carefully, were weighed, and at the end of six days, reweighed. The loss ranged from 8 per cent to 20 per cent, or an average of 12 per cent, and the larger ones invariably showed the greater reduction, the two heaviest, of 220 and 246 grammes, respectively, losing 18 per cent. As no solid matter was excreted, the loss is clearly

* After this had been written I was informed by the shipper that the temperature of the iced car, ten hours after sealing, was 40°F.

due to evaporation of the contained water or that of the organic fluids, for several check experiments demonstrated that the shell remains constant as long as the contained moisture lasts. It is reasonable to assume that under such conditions, excretion of deleterious gas and secretion of oxygen must decline, and the functional activities of all parts and organs be lowered. The large quahaugs were much less resistant than the small ones, for 90 per cent at least of all dying in the course of the experiments were of that class.

Just here it may be asked: Does not a considerable percentage of old clams normally die every season in consequence of expended energy involved in reproduction, a number, the greater as the environment becomes the less natural? Very little is known of this and many other phases of its life-history, and until fuller and more definite knowledge is available, economic problems, like that under discussion, cannot be satisfactorily solved.

When loaded in box-cars, half or more are under a pressure too great to permit the valves to reopen; for, though they are shut and kept closed by contraction of the adductor muscles, they are reopened automatically by the elasticity of a small hinge, too weak, however, to overcome the increased resistance. Hence it was surmised that oxygen utilization would be greatly reduced, fatal results follow, and in the premises the mortality seemed partially accounted for; but in the light of the following experiments it cannot be regarded otherwise than at best a contributory cause, effective only, if at all, in a high temperature and under faulty ventilation.

August 3, thirteen clams were put under pressure in the laboratory, some in clamps, the rest under heavy weights. At the same time a large one was put into an 1800-c.c. jar of sea-water which had been boiled for half an hour to expel the oxygen. The jar was completely filled, so as to exclude all air, and sealed. It was noticed that the siphons were kept protruding as long as it was confined in the jar. The temperature of the room rose above 70° on two occasions, the maximum being 72°, the minimum 58°, the mean for the seven days being 62½°, 61°, 61°, 65½°, 62°, 66° 66°, or an average mean of 63°. No night temperatures were taken, but they were probably all below 60°. The conditions were certainly very favourable for testing the quahaug's powers of endurance under a fairly uniform temperature, and pointing to a means of minimizing the losses met with in the trade.

August 10 all were released and placed in trays, where they continued to live until removed at the end of the season.

The tests exemplify the clam's great resistance to the lack of oxygen. Philip H. Mitchell (*vide* Bull. U. S. Bureau of Fisheries, vol. xxxii, 1912) demonstrated by carefully performed experiments that forcibly closed quahaugs did not appreciably use any oxygen, but voluntarily closed ones did. His experiments, however, were conducted in a water medium, and while the valves may be closely enough set to prevent entrance of that oxygen-bearing element, it may be somewhat different in an air medium. Indeed the ridged character of the margins of the valves would seem to make it probable. One of his most important findings, however, is that oxygen utilization increases with the temperature, and that the smaller clams show a relatively greater consumption of oxygen than the larger.

To prove whether ventilation was or was not a valuable factor in provisions for marketing clams, the following experiments were made:—

(1) A tight box holding thirty-two was closed August 12 and kept in that condition till August 19 under the varying temperature of the room, which ranged between 58° and 70°. Before being opened, a thermometer thrust through a hole, just bored for the purpose, registered 2° lower than the room. Three clams were dead and five more died during the next two days in the tray to which they had been transferred, making a total loss of 25 per cent.

(2) Another lot of eleven was put into a glass jar, the top being covered with perforated cardboard, and the vessel was set in a tray in 2 inches of water with a jet

playing on it. The object was to maintain as uniform a temperature as possible. Seventeen days after, all were alive. Records of shippers and experiments performed at the station prove conclusively that large clams are less resistant than small ones. Lot No. 1 was half and half, but lot No. 2 was all large. The contrast between these two tests may be better seen in tabular form as follows:—

Lot.	No. of Clams.	No. of days out of water.	Temperature.	No. lost.	Per cent lost.
1...............	32	7	variable........	8	25
2...............	11	17	uniform about 62° F.		

That ventilation and uniform temperature are essential is here strongly emphasized.

Those dying in the course of these studies were microscopically examined, but no cause of death could be discovered. The bodies were wasted, parts shrunken, and the whole general appearance that of an animal dying from enervation due to a lack of nourishment. Generally speaking, no ripe generative elements were found, they had either been shed, or failed to develop into large, sound ova or sperm. In some instances, however, ripe ova and sperm did occur in small quantities, sometimes in the reproductive organs, oftener in the branchial chambers, where the ova were breaking down or disintegrating in the midst of swarms of bacteria and some protozoa.

It is the general belief that the valves of a clam spring apart at death, the adductor muscles relaxing, but such does not seem to be the case, for an immediate examination found decomposition already under way, accompanied with an offensive odour. In the case of such a low organism it does not seem possible to define death as a separate act, for the various parts and organs do not cease their functions simultaneously, and the muscular tissue of the adductors, the strongest in the body, may be the last to do so. In this connection it may be noted that the consignees at Chicago maintained the clams were dead on arrival, though the valves were unopened, but when opened in the usual way, they were unfit for use.

It is difficult to account for the decomposition of the ova. Though the clam possesses great resistance to a lack of oxygen, ova, especially when fertilized, demand a medium rich in that element, and renewed constantly. Lacking these conditions, the ovum generally dies and begins to decay, and where, as in the clam, it is in close contact with the most delicate and exposed part of the vascular system, certain toxic effects, fatal to the animal, may result. To this cause may be attributed, in part at least, the high death-rate of shipment in July, probably the maximum spawning period. The small clams were then nearly immune, and it is significant that ripe reproductive products were found in only one small individual at the station. Had this class already spawned, or not reached the necessary age and development? This question could not be answered at the station, nor could any definite information on the point be obtained from the scientific literature available. Its determination would be of some economic value to the trade, and conservation of the fishery.

In closing the brief report of this investigation, the following recommendations might seem warranted by the facts disclosed, and some at least could be tried at little extra cost over present methods. The trade should seek, as far as possible, to minimize the general loss, maintain the reputation of its goods on the market, and at the same time prevent the recurrence of such enormous losses as those met in 1914.

RECOMMENDATIONS.

1. That the floating trays be moored in water of greater salinity and lower temperature than that referred to above.

2. That more favourable methods of promoting circulation and change of water in the trays be adopted. These would seem to be:—

   (*a*) Wider and more numerous slots.

   (*b*) Shallower trays, or present ones filled to about half their capacity.

   (*c*) Mooring in a more open arrangement, so as to utilize the full benefit of the tide.

3. That stock be shipped in the order of its arrival.

4. That cars be ventilated and kept at a fairly uniform temperature, about 62° F.

5. And that crowding and pressure be avoided as far as possible.

POINTS AWAITING INVESTIGATION.

In the course of the investigation, some biological questions and considerations were suggested which might, in the interests of the fishery and science, be fully examined and settled. These may be summarized in part:—

(1) At what age and size is the quahaug sexually mature, and do large and small individuals spawn at the same time?

(2) What proportion of the clams of the various sizes die normally every year, and does death generally follow the spawning season?

(3) What is the general effect of the retention of ova in the case of clams kept for some time in the open air?

(4) Comparison at intervals of quahaug raked early in May with those on the native beds to determine the growth of the reproductive organs of the former, and the general effect of storage.

VII.

INVESTIGATION OF A DISEASE OF THE HERRING (*CLUPEA HARENGUS*) IN THE GULF OF ST, LAWRENCE, 1914.

By Professor Philip Cox, Ph.D., etc.,

Professor of Natural History, University of New Brunswick, Fredericton, N.B.

(With Two Plates.)

About June 15, a large run of small herring, from 6 to 8 inches long, appeared in the shore waters of the straits and at certain points of the Chaleurs bay. The schools were especially large from Bathurst to Shediac—a littoral of nearly 200 miles—and remained till about the 10th of July. The fish died in great numbers, were washed ashore on the beaches or sand reefs, skirting the coast, or in quiet coves littered the bottom. From various points along the coast reports reached the department, and specimens were sent to the Commissioner of Fisheries, Professor Prince, Ottawa, but he was absent in New Zealand, and the specimens were stored.

The previous year had witnessed a similar phenomenon, but the diseased fish appeared earlier, about June 1, and before the annual run of spawning spring herring had left the coast. The latter became involved in the epidemic, and many died; but, as the season advanced, the large fish became fewer and fewer until only small ones were in evidence.

Fishermen recalled the fact, too, that sixteen years before a similar run of diseased fish had visited the coast, and as schools of young herring are very unusual in those waters, it was suggested that the epidemic may be the determining cause of the movement.

About the 20th of July, 1914, Prof. A. B. Macallum, University of Toronto, and secretary-treasurer of the Marine Biological Board of Canada, requested the writer to examine and report on the matter. Unfortunately the schools had disappeared; but an examination of the coast in the neighbourhood of Richibucto yielded two specimens and a fragment of a third—material altogether too scanty, it was thought, for solving the cause of the epidemic, as the death of these individuals might not be due to the general disease at all. A prompt report of the character of the sickness and general conditions, gathered from fishermen, was made to the Fisheries Department, and there the matter rested, until a careful examination of the two specimens was made at the Marine Biological Station, St. Andrews, the result of which is briefly set forth in this paper.

Here it may be remarked that these specimens (see fig. 1) seem to belong to the sea variety and not the coast variety of herring, for the body is rounder, the dorsal insertion more anterior, and the head not so deep as in the latter; but one of these characters is undoubtedly accentuated by the poor condition due to a wasting disease. If this be so, it would seem as if the epidemic were oceanic and not littoral in its origin, and, as before suggested, the shoreward movement may be a result of the general infection.

The ocean variety visits the Northumberland straits in midsummer and seems to spawn in July, for on the occasion of my visit they were being taken some miles off, in a gravid state, with ripe ova.

NATURE OF THE DISEASE.

Fishermen were agreed as regards the symptoms and general appearance of the dead and dying fish. Many saw sores, abrasions, and discoloured spots, especially on the caudal third of the body. A fisherman who owns a salmon stand on North Beach, Richibucto harbour, "dipped" a quantity and sent them to his family, but numbers were found unfit for the table. The disease was most evident in the flesh of the caudal peduncle.

The schools were described as crowding into very shallow water, and their movements were feeble, irregular, and similar to what might be expected of exhausted and dying fish.

CONDITIONS.

The spring had been late. Cold weather had continued far into June and even the average July weather was cooler than usual. The spring run of coast herring was the poorest for years—the fishery a failure at many points along the coast. Predaceous fishes were no more numerous than in other years, though cod were found closer inshore than usual, and generally refused bait, but were caught freely in salmon nets, an unusual occurrence. In July, jelly-fish were exceedingly abundant, surpassing anything known for years, but it does not seem they were much in evidence during the herring epidemic. The lobster catch, above the average up to the time the herring appeared, suddenly fell off, and even the ubiquitous, greedy crab failed to enter the traps. Food was probably in abundance, the herring dying in the off shore waters as well. No schools of squid were seen.

MATERIAL.

As already remarked, I was able to secure two dead fish only and the caudal part of a third; which, on examination, proved exceeding interesting; and, taken in connection with some of the facts referred to above, leaves little room for doubt that they were victims of the general infection. The specimens were 17·5 and 18 c.m., respectively, in length, and the tail fragment probably belonged to one of the same size and age. One had a sore on the side of the caudal peduncle near that fin, which communicated with a canal-like cavity, extending forward under the lateral line nearly the whole length, but here and there broken into two parallel cavities. No opening occurred on the opposite side, nor was there any on the second fish; but a series of dark patches were seen on all, and dissection revealed the open passages everywhere under the lateral line. The fragment had an opening and a cavity extending forward. The three fish had died of a disease similar to that affecting the fish referred to by the salmon fishermen.

The location and appearance of these cavities are shown in figs. 3 and 4. Comparing them with 5, they are seen to occupy the region of the "red meat" or the highly vascular and nerve tissue beneath the lateral line, which is especially rich in lymph and blood. The walls of these cavities and the adjacent muscular and vascular tissue were largely a mass of minute microscopic organisms of extraordinary protean forms (see figs. 6 to 18, inclusive) and members of that group of parasitic protozoa known as the *Myxosporidia*. They are credited with being the cause of widespread epidemics among fish and other animals. They infest the tissues of the body of their hosts, multiply rapidly and in many cases become lethal, death being due apparently to the gradual exhaustion of the system and certain toxic effects. The parasite was not by any means confined to the tissues mentioned, but occurred in the liver, the kidneys, intestinal tract, and abundantly in the blood found coagulated in the sinuses and auricle.

The method of infection is not fully known, but is believed to be by the mouth and intestinal tract. The minute spores may be swallowed directly by the fish, taken

in with food particles, or parasitic on the bodies of animalculæ on which the herring feeds. The life-history is very complicated, and the cycle of changes and apparent metamorphoses it undergoes surprising, as a glance at the figures appended to this paper will show. For the unravelling of these processes and determining the species, living material is essential, and even then it is one of the most difficult studies a micro-biologist can undertake.

It seems to be a Neosporidium, a member of a group of Myxosporidia which are propagated by means of spores. The spores are provided with a dense ectosarc which serves as a protective cell-wall, and are technically known as "sporon's." The envelope is digested in the stomach or enteric canal and the parasite liberated in the form of an amoebula, which, partly owing to its minuteness and partly to the power of altering its shape to suit conditions, penetrates the epithelial lining, enters the blood-currents, and is carried to the special tissues to be infected. This amœbuloid form has been designated by Stempell a "planont," from the wandering habit; and the one under discussion seems to be intercellular, that is, occurs very generally lodged among the fibres of tissues, especially of the muscular and vascular tissues, which may become wholly disintegrated or destroyed by enormous swarms of the parasite. Constantly bathed in lymph, the Neosporidium ingests its food by absorption alone, so that the pseudopods seem to aid the parasite in insinuating itself among the fibres and increasing the extent of absorbing surface. Under these favourable conditions it multiplies in a surprising manner.

Though the life-history of the parasite could not be satisfactorily made out, the absolute character of some phases could; and reading in between them the scanty knowledge of the group available, certain relations of these phases were rendered probable. For instance figs. 11, 12, 13, and 14 plainly suggest a succession, eleven being theoretically the initial stage of the series. It is clearly a plasmodium or multinucleate cell, to be presently resolved into a large number of uninucleate cells, known as "meronts" and represented by fig. 13, rounded off in fig. 14. The multi-nucleate cell is generally believed to arise from the sporont, and some evidence to that effect was obtained during the study of the material, but the structure of the sporont made the initial steps of the development hard to follow. For instance: instead of the chromatin being more or less aggregated into a nucleus and a near nuclear investment, it was largely distributed through the whole cytoplasm in the form of granular chromatids and obscured more or less with melanin, so that the nucleus, even when stained, could be seldom seen, and hence the first stages of nuclear division were not clearly made out. Indeed some authors doubt that the sporont possesses a nucleus at all. It was only when the division of the nucleus, if it has one, had advanced somewhat, or the wandering chromatids had been attracted to certain points (multinuclear centres) that the phase became evident. Again, it could not be determined whether the multi-nucleate cell arose asexually or was the result of a previous conjugation of gamete sporonts. It undoubtedly represents one method of rapid multiplication.

Few instances of binary fission were met with, one of which is represented in fig. 19, but many of the protean forms suggest budding, a condition rendered quite probable on account of the nuclear elements being scattered throughout the whole cytoplasm. Indeed many of the pseudopodial enlargements were seen to be rounded distally and the chromatids more or less aggregated after the manner of an ill-defined nucleus, the whole suggesting new cell-formation by gemmation.

While all stages were to be found in any affected tissue, the meronts were most abundant in that least affected; the sporonts or resistant spores, where disintegration was most advanced; and the planont stage largely characterized the blood, liver, intestines and kidneys, though in the latter confined to the blood vessels.

Contamination is effected by the sporont, or at least such is the general belief, but the precise manner of transmission is in doubt. Granted some means of con-

veying them from infected hosts to the water, the rapid contamination of fish, schooling densely like the herring, must follow, but such means do not seem to be directly provided in all cases. For instance, one of the specimens had an opening on one side of the caudal peduncle, the other had none. In the former case suppuration doubtless carried out swarms of sporonts to enter other hosts and spread the infection, but many hosts seem to die in the progress of the disease before openings appear and sloughing is possible. It does not seem that many are voided through the natural openings, for their numbers in the intestinal tract, ovaries and spermaries are insignificant when compared with the masses to be found elsewhere. It may be surmised that the parasite has other hosts, and among them small organisms on which the herring prey. It is only necessary to add that once the protozoan has entered a host its wonderful power of rapid multiplication, absorption of the vital fluids and general clogging and disordering of the vascular system, especially of the blood vessels, must soon produce results highly lethal.

Since the above was written, I received two lots of herring from Dr. Macallum: lot No. 1, collected at Metis, P.Q., and lot No. 2, taken by Captain Wakeham at some other point, the exact locality unknown to the writer. These fish were reported diseased and dying. Indeed it seems as if a general epidemic was abroad among the herring of the coast waters of Canada and Newfoundland during the spring, summer and autumn of 1914. The first report came from Newfoundland, as the following clipped from the St. John *Globe*, which was copied from the Eastport *Sentinel*, will show:—

"Enormous quantities of dead herring are being found in the waters surrounding Newfoundland, and fishermen are worried. Many look upon it as a plague, and as the beginning of the end of the herring fishery, which, should it occur, means dire poverty and distress in its very worst shape to thousands of people there."

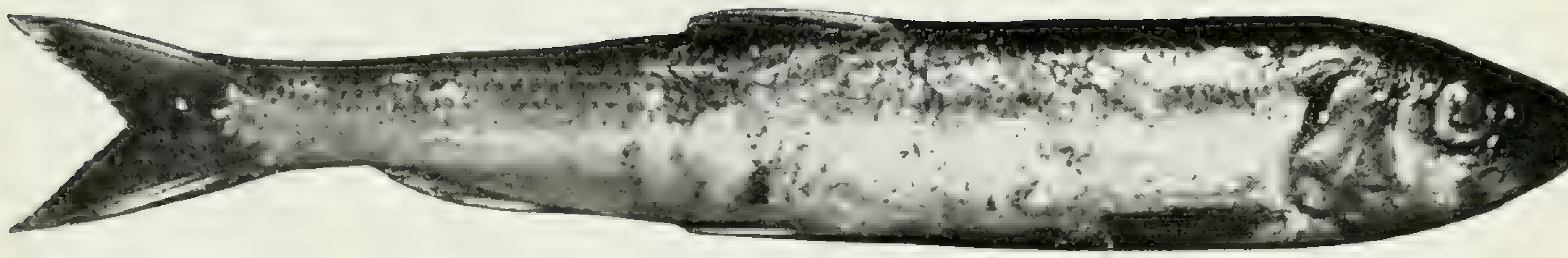
This was in April, and about the middle of June it appeared among the schools along the New Brunswick shore. Later it seems to have become pretty general at other places in the gulf. It is just possible that all these fish belonged to one great migrating body.

Lot No. 1 was made up of small fish from 6 to 8 inches in length and apparently of the sea variety, being in all respects similar to the New Brunswick specimens. The cause of death was the same in all cases. The parasite was especially abundant in the coagulated blood of the heart and sinuses, the lateral line tissue was badly affected or entirely destroyed, and sores were seen on the caudal peduncle, close to the fin.

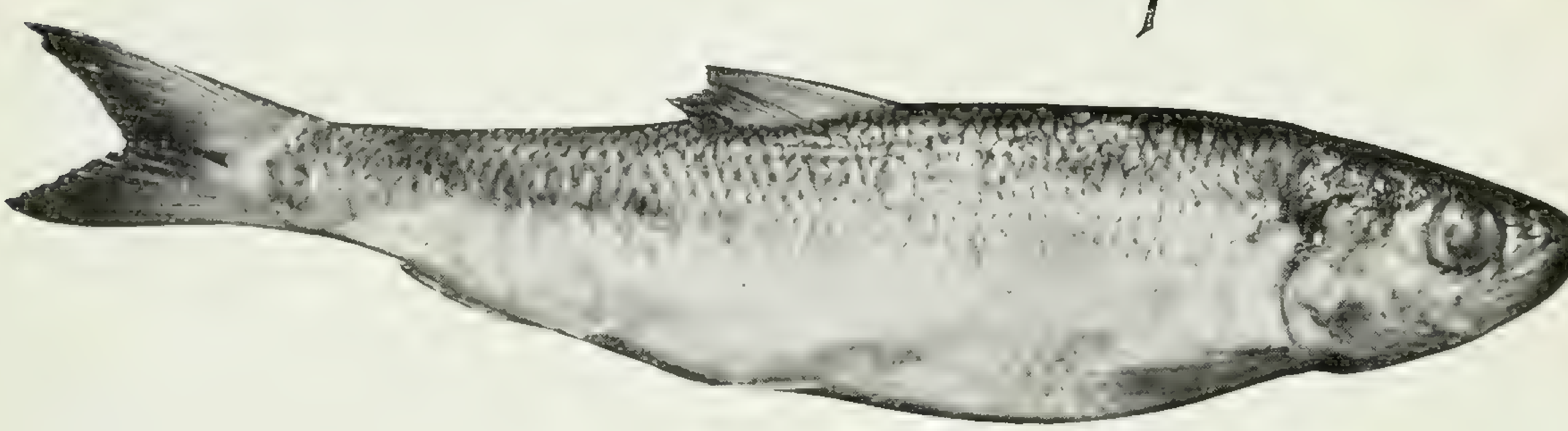
Lot No. 2 was composed of larger and better conditioned fish, averaging from 11 to 12 inches in length. A few showed abrasions of the skin, apparently due to chafing against stones when dead, but the tissue here seldom contained any parasite, except in the case of a very badly affected fish. Some had small sores in the axils of the pectoral fins which seemed to open into diseased pockets where the contiguous tissues literally swarmed with parasites, generally in the sporont stage. The extra flow of blood to these parts may account for the colonies. A few axillary sores, however, seemed due to some external parasite, probably a crustacean, for the protozoan did not occur in the neighbouring tissue. In one, a well-conditioned and preserved specimen, no parasites were found, and the cause of death was probably due to an accident.

No Neosporidia were found in the brain, and the larger and least contaminated fish showed an immense number of plasmodia or multinucleate cells, see figs. 11-14, which seem to be characteristic of the initial, as the sporonts are of the final stages of the disease.

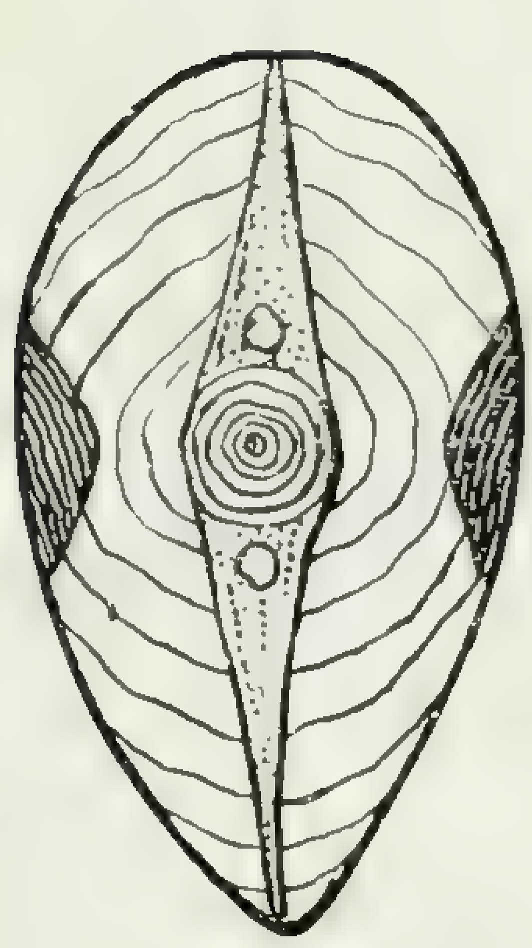
Herring Disease. Philip Cox.



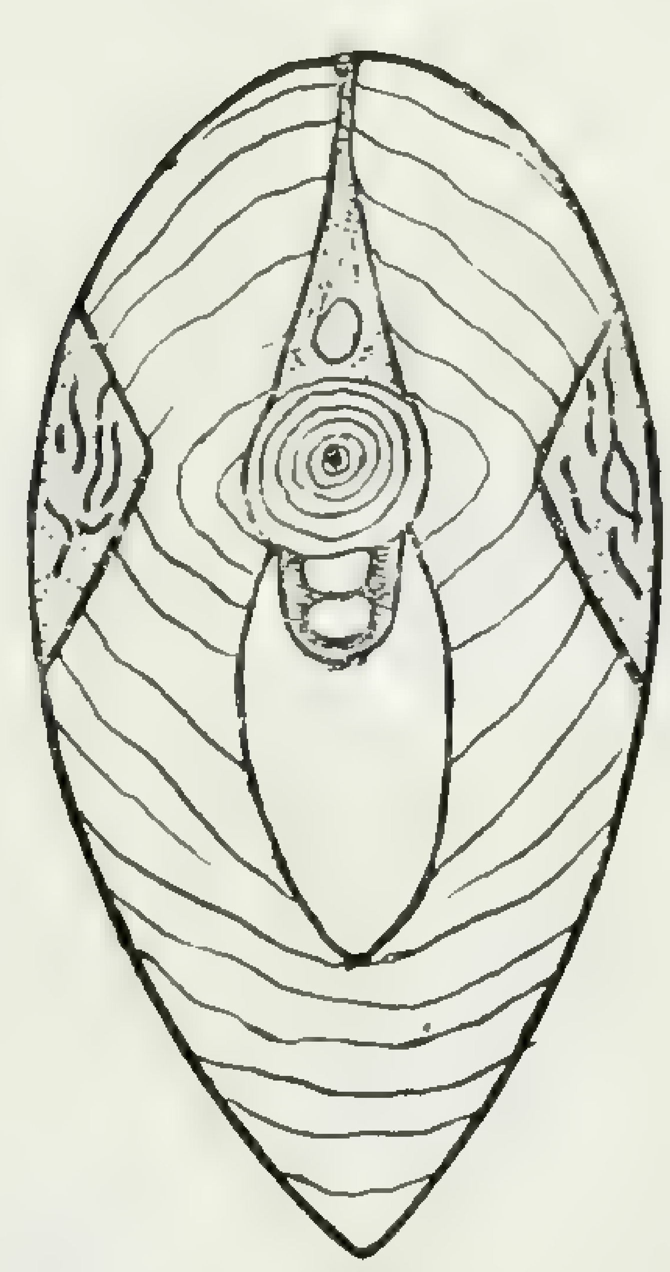
1



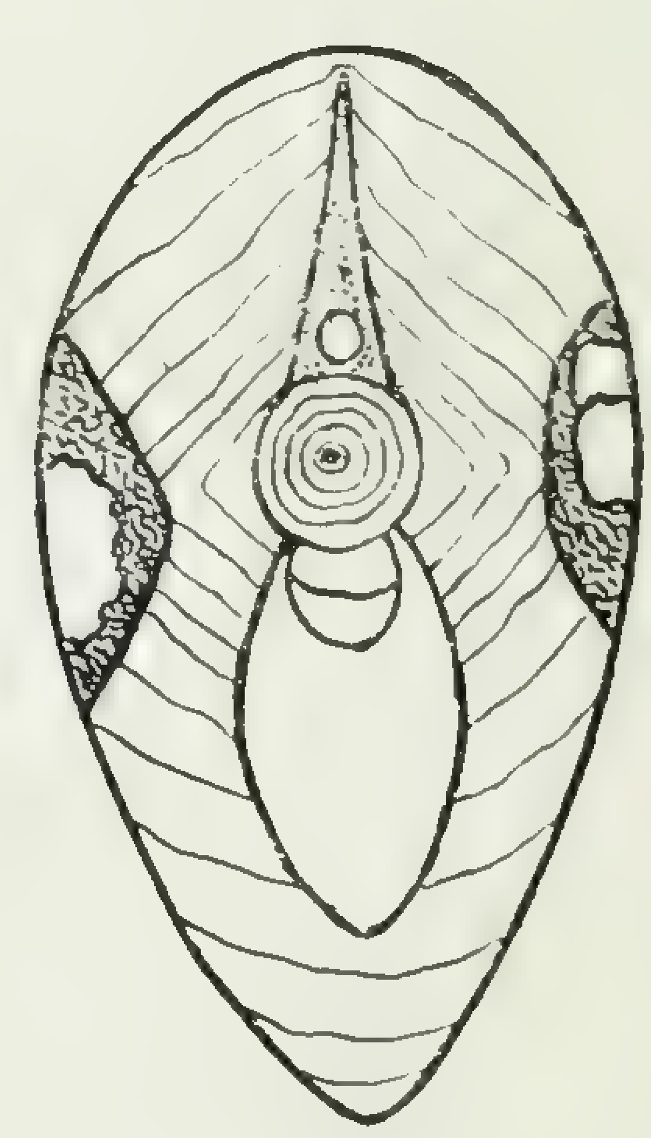
2



3

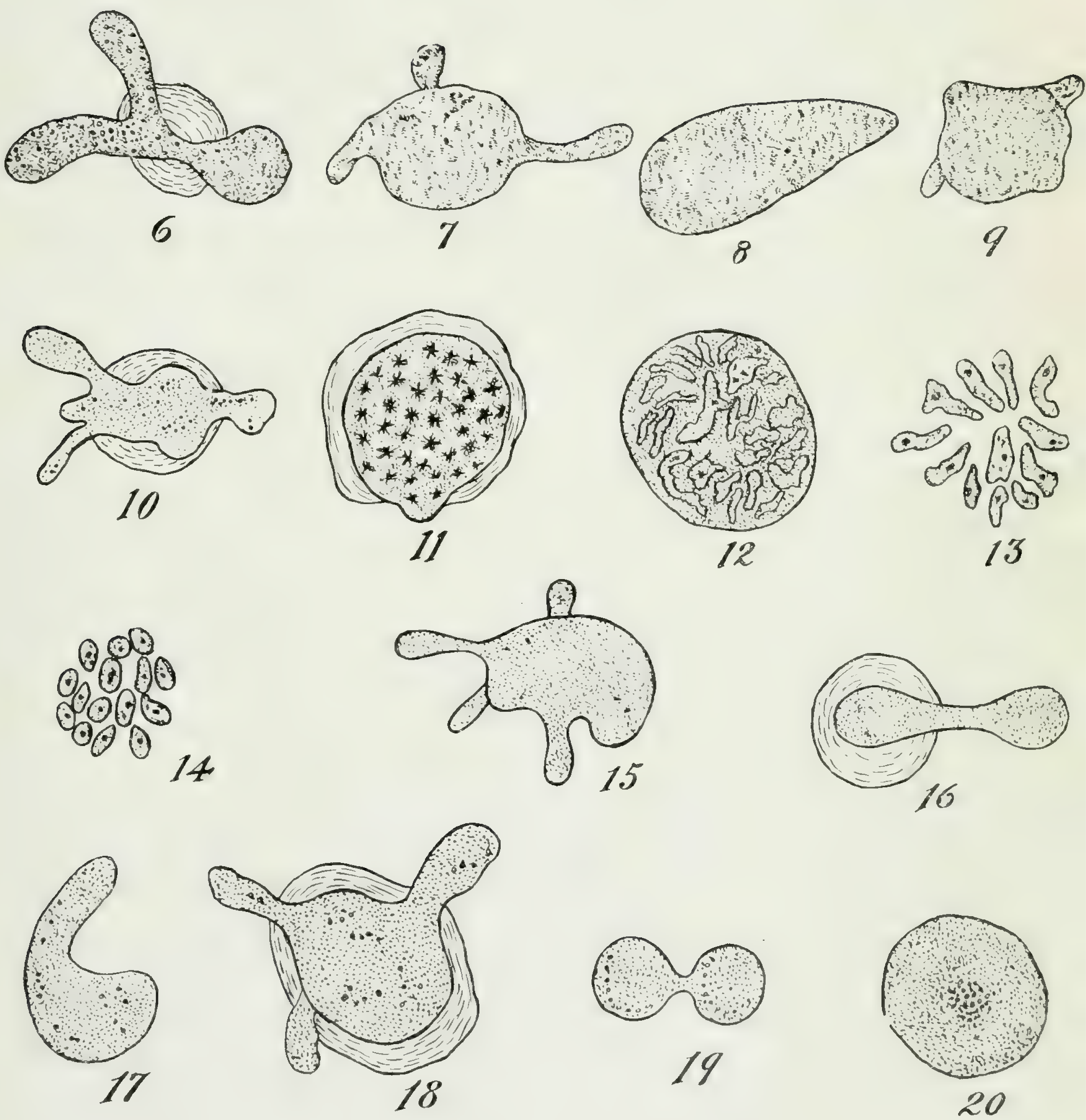


4



5

Herring Disease. Philip Cox.



EXPLANATION OF PLATES.

Plate VIII.

Fig. 1. Diseased Richibucto Herring.

2. Coast Herring, Passamaquoddy Bay.

3. Cross-section. Lateral line tissue shaded.

4. Cross-section. Dark lines in lateral region marked early stage of disease.

5. Showing excavation of lateral line tissue.

6–10. Protean forms of planonts. The "shell" is represented in 6 and 10.

Plate IX.

Figs. 11–14. Plasmodia or multinucleate cells.

15–18. Further planont forms.

19. Apparent cell division.

20. Sporont.

All magnified from 600 to 1,400 times.

VIII.

THE LIFE-HISTORY OF THE HAKE (*UROPHYCIS CHUSS* GILL) AS DETERMINED FROM ITS SCALES.

BY E. HORNE CRAIGIE, *University of Toronto.*

(With Seven Figures.)

The object of this investigation was to determine the rate of growth of the hake by an examination of the scales and comparison of the data thus obtained with the length-frequency curve.

In all, 780 hake were examined, representing several different catches, as follows:

No. 1. North Channel, June 15, 1914.

Nos. 2–50. North Channel, July 7, 1914, in the afternoon.

Nos. 53–100. Wilson's Beach, July 16, 1914.

Nos. 101–228. Wilson's Beach, July 22, 1914.

Nos. 229–352. Wilson's Beach, July 30, 1914.

Nos. 353–780. Wilson's Beach, July 31, 1914.

In the case of Nos. 1 to 52, inclusive, the length was recorded and scales were taken. Nos. 53 to 227 were also weighed, and their sex, the weight of the gonads, and the weight of the livers were recorded. In the remaining cases only the length and sex were recorded, in order to get data for a length-frequency curve.

The measurements of the first hundred fish were made with a folding rule, while the remainder were measured by placing them upon a board marked off into centimetres. In every case the measurement was made from the tip of the snout to the posterior end of the vertebral column.

The scales were taken from the side of the fish either a little above the lateral line or just below the dorsal fin. A considerable number were prepared by soaking in water, cleaning thoroughly with a small brush, and mounting dry in microscope slides. It was found, however, that they kept perfectly in paper, and could be examined quite readily, as when in permanent mounts, if simply wet, and placed upon a clean slide, the surplus water then being removed with a piece of clean filter paper, and this method was used in most of the work.

Curves were drawn with the lengths of the fish as abscissæ and the frequency as ordinates. One such length-frequency curve was drawn for Nos. 53–352 (fig. 1), which will be seen to show a typical "hat curve" for each sex, that for the males being particularly smooth and showing a predominance of fish 43 cm. long. The curve for the females, on the other hand, shows a marked predominance of individuals between 47 cm. and 50 cm. in length, the greatest number being 50 cm. One curve drawn for both sexes shows two humps corresponding to those on the curves for separate sexes, showing that there is not even sufficient overlapping of the sizes of the two sexes to smooth out the curve.

Graphs drawn for Nos. 353–780 (fig. 2) show even more strikingly regular "hat curves," and also show the same difference between the predominating size of the two sexes. From these graphs it appears, in the first place, that the fish of a given sex associate almost entirely with individuals of their own age, as there is only one marked hump in each curve. In the second place, it is evident that either the males of the age represented are smaller than the females of the same age, or else the

females associate with males which are younger than themselves. An examination of the lines of growth upon the scales indicates that the former is the correct explanation of the facts, the individuals of the two sexes being the same age.

The morphology of the scales of the hake differs entirely from that of the scales of the cod, haddock, etc., and bears some resemblance to that of the salmon scales There is no succession of spiral, cyclic, and crescentic rings. The nucleus in the centre of the scale is occasionally a short spiral, and in a few cases is a complete ring, but usually it is a ring with a little break at the anterior end. Such rings, in the form of a somewhat irregular ellipse continue, more or less uniformly spaced, until the end of the ellipse reaches the end of the scale, leaving a perfectly clear strip extending along the long axis of the scale from the centre to the anterior end. The

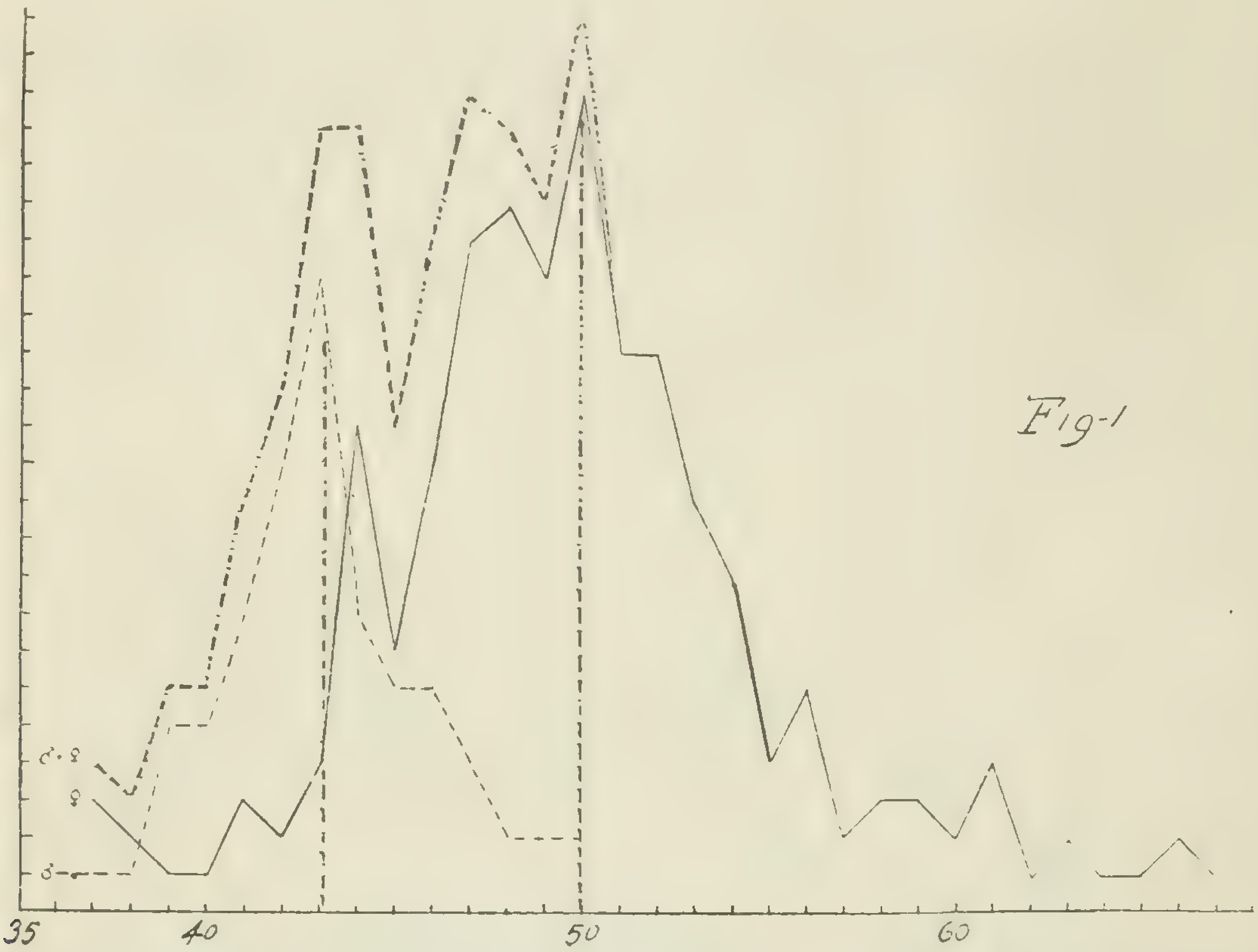


Fig. 1.—Length-frequency curves for specimens of hake Nos. 53-352. The clear line represents all the females, the interrupted line all the males, the dotted line represents the two sexes taken together. Dotted vertical lines represent means.

rings then continue to the edge of the scale as curved lines along each side. In some cases these lines, or rings, extend right to the extreme edge of the scale at each end, but most scales have a narrow clear area along the posterior edge.

The lines of growth, instead of being formed by a change in the nature of the rings, are merely shady lines produced by a little irregularity in each ring along the side of the scale and a roughened area across the posterior end. Where these lines reach the clear area on the long axis they are marked by the ring nearer the centre stopping abruptly at the clear space, while the next ring turns and runs along the edge of this space for some distance towards the outside of the scale. It is this change in the rings at the clear space which is considered to suggest the condition in the salmon, where the rings alter in such a way as to form caps. These lines of growth are sometimes very indistinct but are usually quite evident, though a little indefinite. In several scales the distance of the innermost line from the centre would seem to indicate that the first line is missing.

That these lines represent a periodicity in growth there is no doubt, but whether or not they are annual there is at present no means of determining, though this is

probably the case. In the tabulated data the number of these lines of growth has been recorded under the heading "Age." In three cases "(inter)" has been inserted after the number to indicate that one ring has been "interpolated," it being considered that the first ring appearing probably represents the second recurring period in the age of the fish.

Fig. 2.—Length-frequency curves for specimens of hake Nos. 353–780. The clear line represents all the females, the interrupted line all the males. Dotted vertica lines represent means.

Almost all the fish examined appeared to be 3 years old (if it be assumed that the lines of growth are annual), one of the lines appearing in almost every case very near to the edge of the scale. An attempt was made to draw length-frequency curves for the two sexes at different ages, but there were not enough either two-year-old or four-year-old individuals to form curves at all. This is greatly to be regretted, as it

would have been a valuable check upon the curves for different ages as determined by assuming the growth of the scales to be proportional to that of the fish, which are described below. The curves for the three-year-old fish (fig. 3) naturally showed little difference from the length-frequency curves for all of the sex, the same humps appearing distinctly in each case.

Whether the growth of the scale is proportional to that of the fish could not be definitely determined owing to the impossibility of comparison of curves obtained upon this assumption with ordinary length-frequency curves for different ages. The assumption was made, however, and certain deductions were drawn as to the rate of growth.

A scale was placed under a low power of the microscope, and by means of a camera lucida a line was drawn, representing the long axis of the scale from the centre to the anterior extremity, and the positions of the lines of growth were marked upon this line (fig. 4). Another line, representing the short axis from the centre to one side was similarly drawn and marked off, the two lines being so placed that they formed a

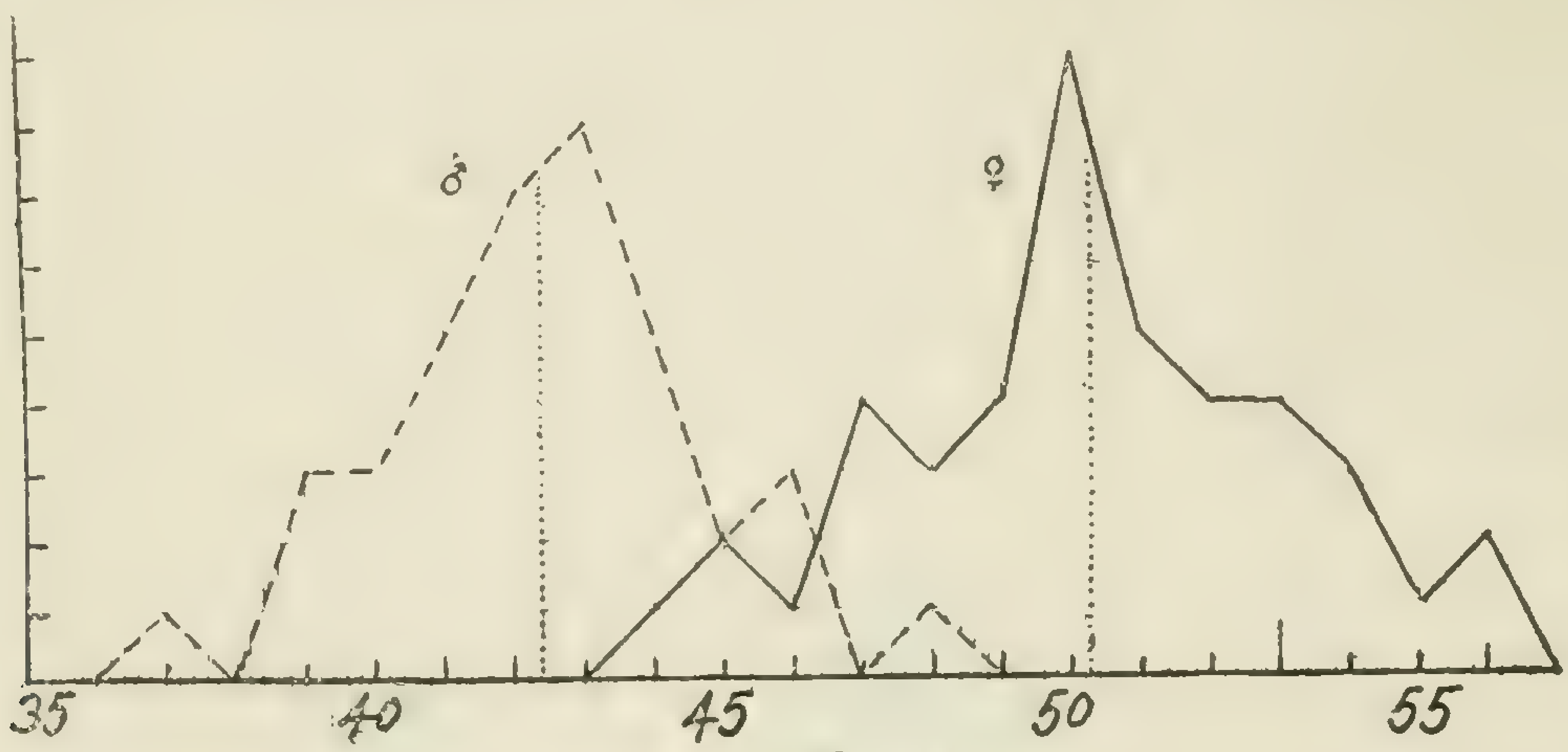


Fig. 3.—Length-frequency curves for 38 male and 42 female hake all three years old. Curve for females a continuous line, curve for males interrupted line. The positions of the means are indicated by dotted lines.

wide angle, the ends representing the outer ends of the axes coinciding. Between these lines there was then drawn from the angular point a third line representing the length of the fish, the scale being 2 mm. to 1 cm. Straight lines were now drawn from the ends of the two lines representing the axes to the end of the third line, and lines were drawn parallel to these from the positions of the lines of growth to meet the line representing the fish. In this way the length of the fish at the end of each year of its life was determined graphically. Unfortunately it was found that the two axes gave different results, and there was no fixed relationship between them. For this reason the construction was always made for both axes, as described, and the average of the two results was taken. In several cases the construction was made for more than one scale of the same fish. The results obtained in this way differed just as irregularly as did those given by two axes of the same scale, and again the average was taken.

Fifty females and forty-five males (all the males of which scales had been taken, except a few in which the number of lines of growth was doubtful) were examined in this way, and length-frequency curves were drawn for the different ages of each sex (Figs 5 and 6) from the lengths calculated as above, upon the assumption that the growth of the scales is proportional to that of the fish. Two of the lengths calculated for males at the end of the first year, one at the end of the second year, and two at

the end of the third year came so far outside the range of the curve that they were excluded entirely, as were also one first-year length and two third-year lengths of females, for the same reason. The curves obtained for the males were considerably smoother than those for the females, but fairly satisfactory results for the first three years were obtained for both sexes. The graph obtained thus for males at the end of

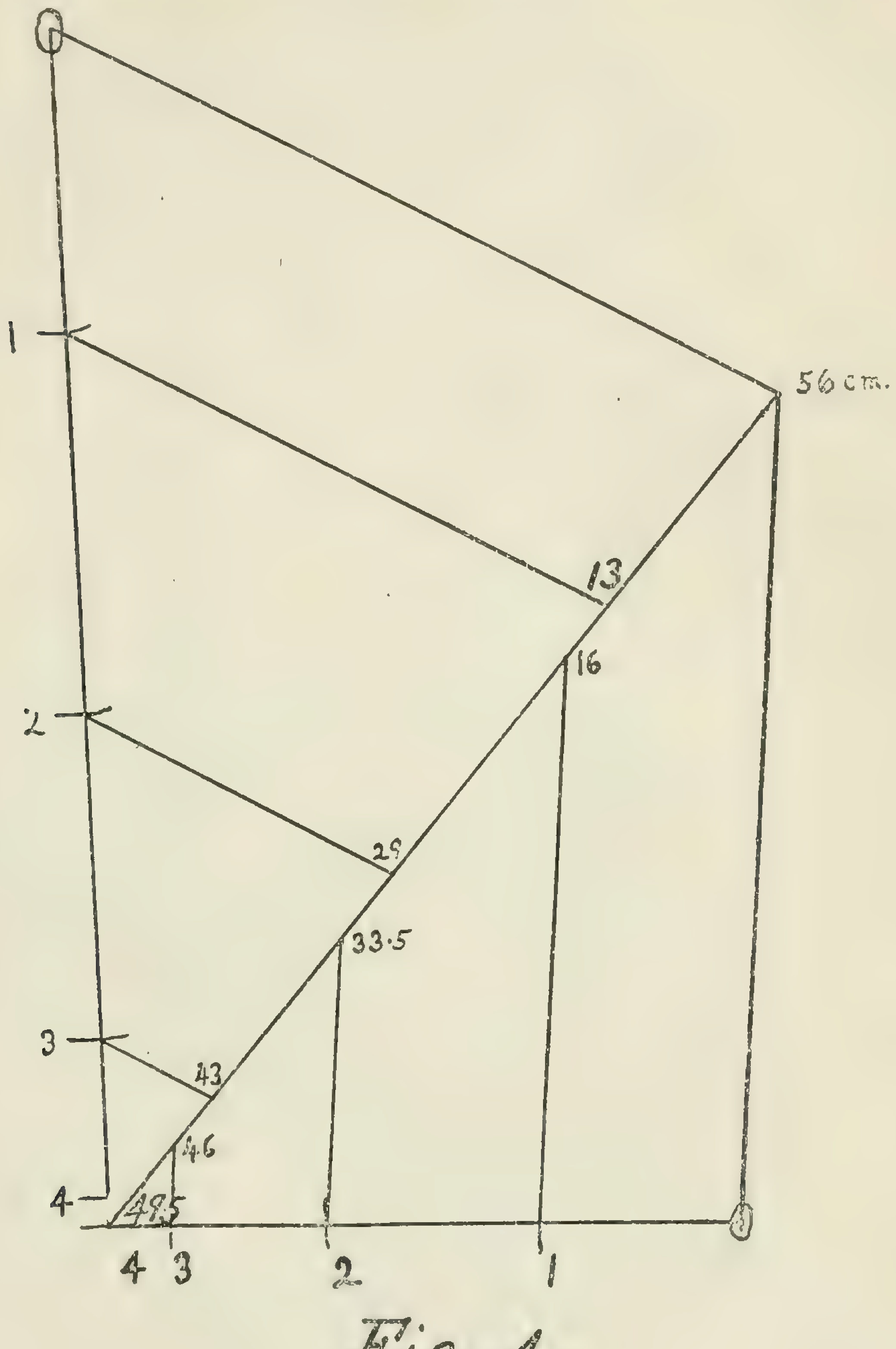
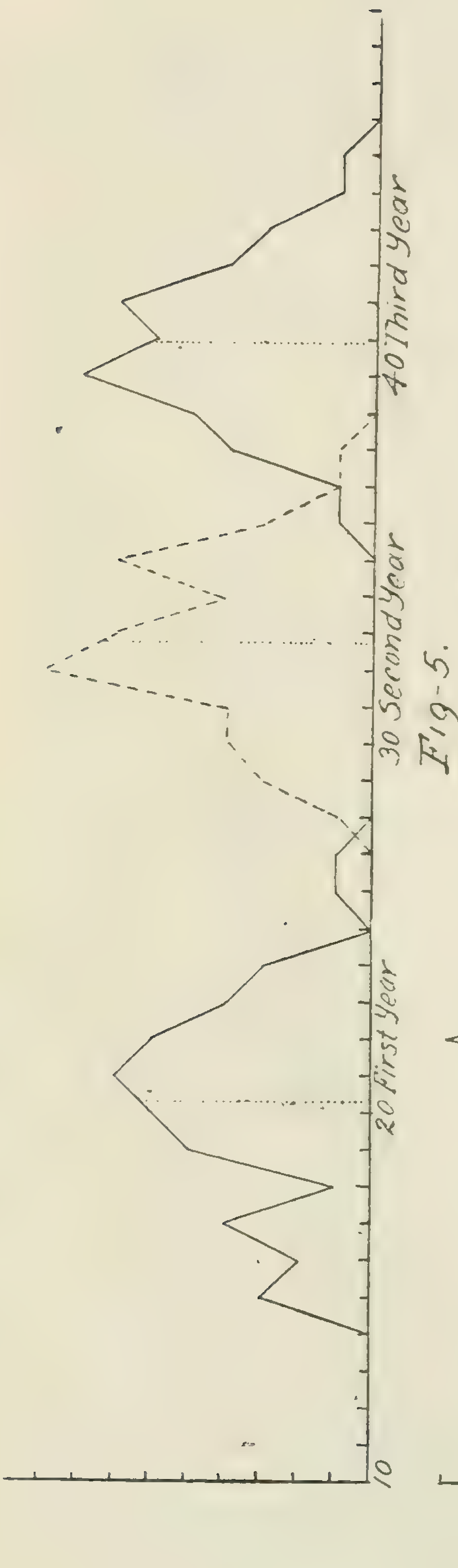


Fig. 4.—Scale diagram for female hake No. 83.

their third year closely resembles that for three-year-old males, the hump being for a little smaller size, as the three-year-old individuals had already grown somewhat in the early part of their fourth year. The same remark applies to the graph for the females. The mean for each age and sex was calculated, and is indicated in the figures (figs. 5 and 6). If these be compared with fig. 3 it will be observed that the mean of the male curve is about 1·5 cm. larger and that of the female curve about 3 cm. larger in the latter, owing to the growth in the part of the fourth year which had elapsed before capture.



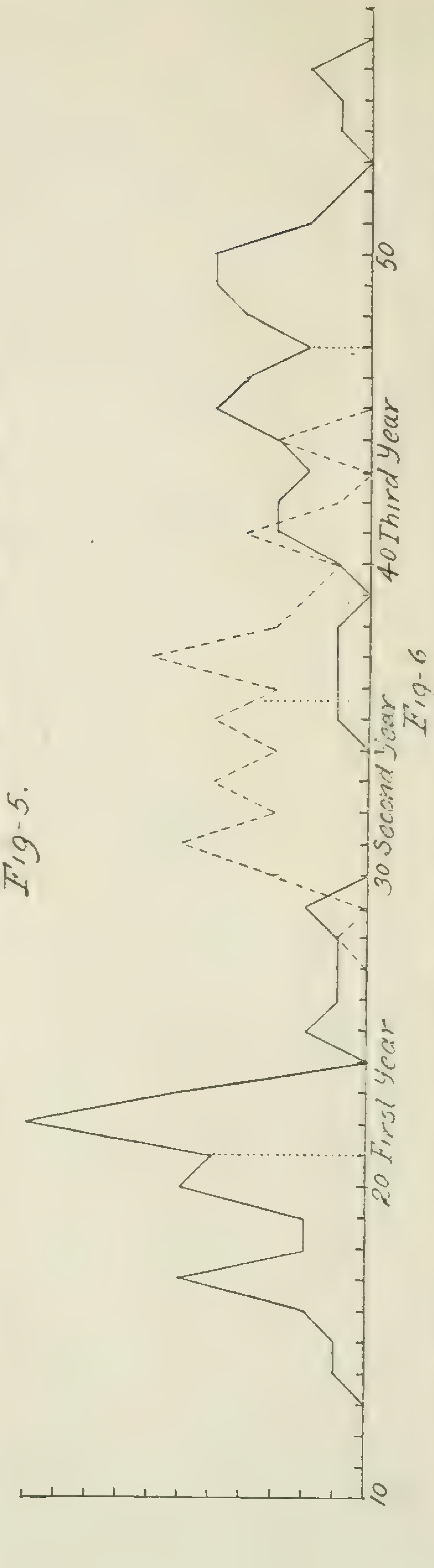


Fig. 5.—Length-frequency curves for 45 male hake based on lengths determined from scale diagrams. The position of the mean is indicated by a dotted line.

Fig. 6.—Length-frequency curves for 50 female hake based on lengths determined from scale diagrams. The position of the mean is indicated by a dotted line.

Taking the means of the curves based upon the scale diagrams as ordinates and the corresponding number of years as abscissae, a rate of growth-curve was now constructed for each sex (fig. 7). These curves show that the rate of growth is fairly uniform during the first three years, but is greatest in the first year, as would be expected, and decreases in each of the two succeeding years. They also show that the difference between the rates of growth of the two sexes increases in each succeeding year. It appears besides that the species is a rapidly growing one, while the uniformity of the curve indicates that it does not spawn before the fourth year, the spawning period always being marked by a decrease in the rate of growth.

The mean weights were calculated for the thirty-eight males and for the forty-three females in their fourth year, of which the length-frequency curves are illustrated in fig 3. The mean weight of the males was found to be 957 grams, while that

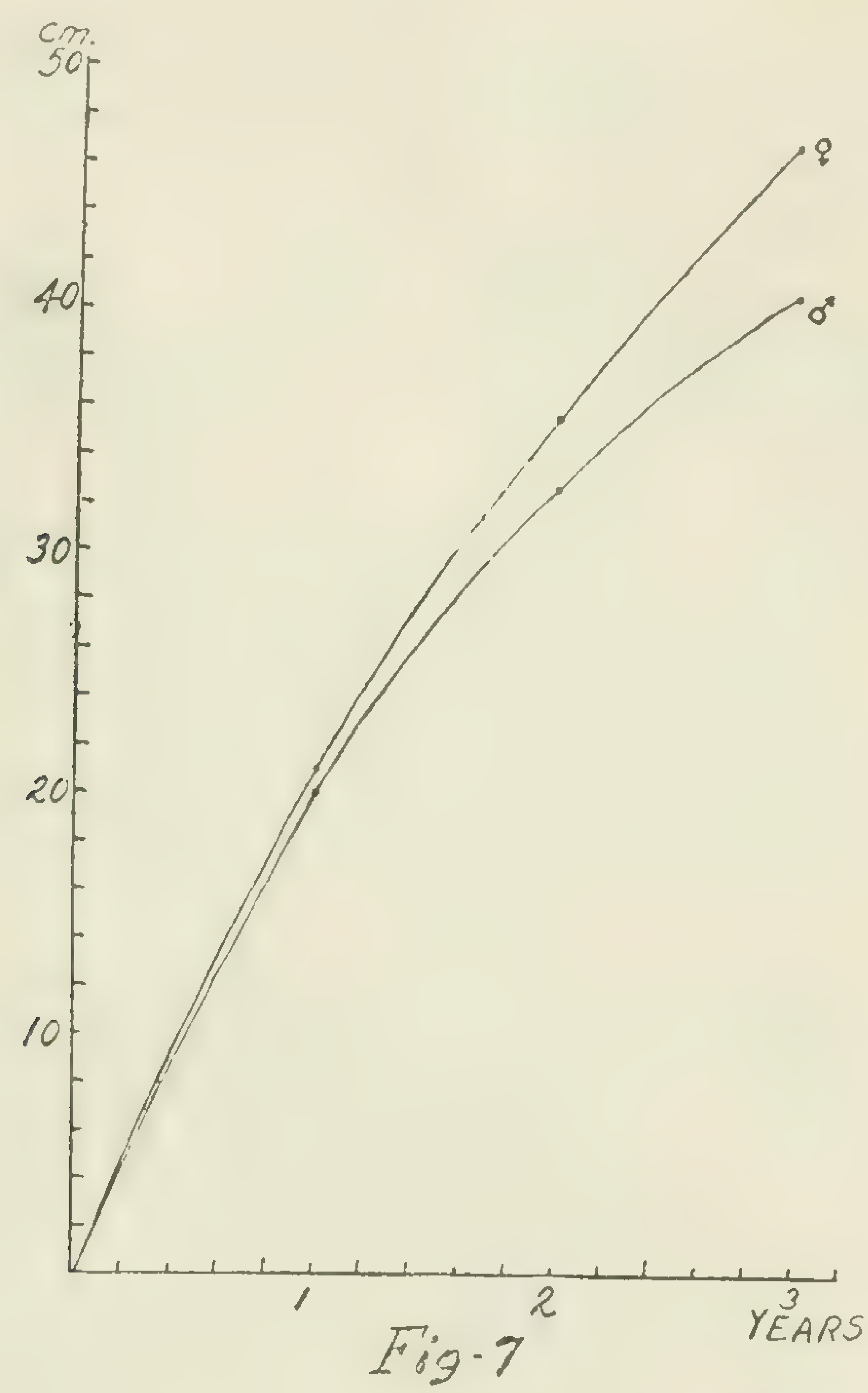


Fig. 7.—Rate of growth curves for male and female hake constructed upon the basis of the curves in Figs. 5 and 6.

of the females was 1,440 grams, showing that the females exceed the males in weight as well as in length. The ratio of the mean weight of the males to that of the females is ·642. If the cubes of the mean lengths, as marked in fig. 3, be calculated it is found that their ratio is ·604. Thus the excess in weight of the females over the males is a little less than one would expect from their excess in length, indicating that the males are generally slightly thicker than are the females in proportion to their length. This conclusion with regard to the shape of the males may not be justified, however, as the ovary, etc., are lighter than muscle, so that the female may exceed the male in bulk more than she does in weight.

As a sample of the data obtained, the records for fifty fish are tabulated at the end of this paper. The dates and locality will be found upon the first page of this paper.

In addition to the data already referred to, evidence was obtained to show that either the females are much more numerous than the males or the individuals of one sex associate in separate shoals. Among the forty-eight fish examined on July 16 (Nos. 53 to 100) there were only two males; among the one hundred and twenty-eight examined on July 22 there were forty-six males; among the one hundred and twenty-four examined on July 30 there were thirty-five males; among the four hundred and twenty-eight examined on July 31 there were one hundred and thirty-one males. From these figures it would appear that the second explanation suggested, namely, that the females are much more numerous than the males, is the probable one.

SUMMARY.

Thus in the investigation of the life-history of the hake, 780 individuals were examined. From the data obtained, length-frequency curves were drawn which showed that the average length of the females examined was greater than that of the males. An examination of the scales indicated that these males and females were the same age. Thus it appeared that the shoals are composed almost entirely of fish of one age and that the females are longer than the males of the same age. It is unfortunate that practically all the fish examined were in their fourth year. These fish were representative of all those caught in the St. Andrews district during the season, the size of all the hake brought in being remarkably uniform. Length-frequency curves for the individuals of either sex in their fourth year were drawn, and these were compared with length-frequency curves for the sexes at the end of each year of their growth, constructed from the lengths calculated from scale diagrams, upon the assumption that the growth of the scales is proportional to that of the fish. In preparation for the determination of age, and the construction of scale diagrams, the morphology of the scales was carefully examined. It should be mentioned that the vertebrae of a considerable number of individuals were cleaned and examined as a basis of age determination, to be a check upon the scales. It was found, however, that the rings of growth were too indefinite to be of much service, and this method was soon abandoned.

Finally, from the means of the length-frequency curves based upon the scale diagrams, rate of growth curves for the two sexes were constructed. These showed in the first place, that the rate of growth was fairly uniform during the first three years, indicating that spawning does not take place before the fourth year; in the second place, that the rate of growth decreases in each succeeding year for the first three years; in the third place, that the excess in rate of growth of the females over the males increases in each succeeding year during the same period.

In concluding this report I wish to express my appreciation of the direction and assistance of Dr. J. W. Mavor in the accumulation and working up of the data, and also of the assistance afforded in the former part of the work by all the members of the staff at the St. Andrews Biological Station in 1914.

IX.

INVESTIGATION OF THE HADDOCK FISHERY, WITH SPECIAL REFERENCE TO THE GROWTH AND MATURITY OF THE HADDOCK (*MELANOGRAMMUS ÆGLEFINUS*).

By Dorothy Duff, M.A., *McGill University, Montreal.*

The objects of this investigation at the Marine Biological Station, St Andrews, N.B., were as follows:—

(1) To test the method of determining the age of the haddock by the study of the periodic rings of growth on the scale, and to calculate the rate of growth of this fish from the rate of growth of its scales, as has been done for the herring and cod in the North sea.

(2) To determine, by measuring representative numbers, the size most abundant in the catches. This to enable us to form some idea of the haddock population and the general condition of the haddock fishery in this region of the North Atlantic.

(3) To calculate the yearly increase in weight and to find the relation of the weight to the length.

(4) To determine whether there was any marked difference in size and weight between fish of the same age but of different sex.

(5) To find the age of maturity for the haddock, that is the age at which they first spawn.

(6) To gather data leading to the determination of the season of the year when the spawning occurs, and the duration of the spawning period.

(A) MATERIALS OBTAINED AND EXAMINED.

We have examined 460 haddock. These were taken at random from twelve different catches, caught on baited trawls during the months of June, July, and part of August, 1914. They are numbered as follows:—

(1) Numbers 1 to 10—
Caught in St. Mary's bay, Nova Scotia.
Examined—The Fish Market, St. Andrews.
Date—June 10, 1914.

(2) Numbers 11 to 46—
Caught—St. Mary's bay, Nova Scotia.
Examined—The Fish Market, St. Andrews.
Date—June 11, 1914.

(3) Numbers 48 to 57—
Caught—North channel, between Grand Manan and the Wolves.
Examined—Wilson's beach, Campobello island.
Date—June 15, 1914.

(4) Numbers 58 to 65—
Caught—Off North head, Grand Manan island.
Examined—North Head harbour, Grand Manan.
Date—June 22, 1914.

(5) Numbers 66 to 98—
Caught—Letite Passage.
Examined—The Fish Market, St. Andrews.
Date—June 24, 1914.

(6) Numbers 99 to 128—
Caught—North channel.
Examined—The Fish Market, St. Andrews.
Date—June 25, 1914.

(7) Numbers 129 to 131—
Caught—Mouth of the St. Croix river.
Examined—Biological Station.
Date—July 2, 1914.

(8) Numbers 132 to 138—
Caught—North Channel.
Examined—The Fish Market, St. Andrews.
Date—July 7, 1914.

(9) Numbers 139 to 144—
Caught—Mouth of the St. Croix river.
Examined—Biological Station.
Date—July 8, 1914.

(10) Numbers 145 to 166—
Caught—Off the Wolves.
Examined—Wilson's Beach, Campobello island.
Date—July 16, 1914.

(11) Numbers 167 to 174—
Caught—Mouth of the St. Croix river.
Examined—Biological Station.
Date—July 30, 1914.

(12) Numbers 175 to 461 (representing all the fish of one catch)—
Caught—North channel.
Examined—The Fish Market, St. Andrews.
Date—August 4, 1914.

(B) MODE OF MEASUREMENT.

For measuring the length of the specimens of fish studied a "measuring board" was used. This consisted of a board marked with parallel grooves one centimetre apart and having at one end a short upright piece. The fish to be measured were placed with the end of the snout against the upright and the length to the end of the caudal vertebræ (easily ascertained by feeling) measured to a half centimetre. Every length was recorded as the nearest greater centimetre or half centimetre.

The length-frequency curves made from these measurements are shown in Fig. 1. Curve B represents all the fish of the first eleven catches. This first curve clearly resolves itself into six humps, which probably represent six-year classes of haddock. In the curve A, which represents one catch of three hundred fish (294 to be exact), these classes are somewhat obscured by the abundance of one class between 45 and 50 centimetres long. However, at least five distinct prominences can be seen in the curve. A study of these length-frequency curves shows that the lengths may be assigned to the following year-classes:—

Class.	Length in Centimetres.	Average length of class.
1	33-40	36·5
2	40–45	42·5
3	45–50	47·5
4	50-58	54
5	58-64	61
6	64-70	67·5

Curve C indicates these classes as shown in curve B.

An insufficient number of fish have been examined to enable any conclusions to be made with regard to the relative abundance of the different year classes in Passamaquoddy bay.

(c) STUDY OF SCALES TO DETERMINE AGE OF HADDOCK.

Scales were obtained from the fish of the first eleven catches examined. Those of seventy-four have been carefully studied. The scales were taken from the shoulder, above the lateral line just behind the head. They were washed in water, brushed with a small stiff paint brush to remove the mucus and epidermis, and mounted dry between two slides.

The morphology of the gadoid scale has been carefully worked out by Dr. Damas in connection with the North sea investigations. He examined the scales of the cod which very closely resemble those of the haddock. The haddock scale is ovoid and when magnified appears to be made up of numerous concentric rings. The distance of these rings from one another varies in a definite periodic manner. The first rings about the nucleus are relatively wide apart, outside these the rings come close together forming a so-called "winter ring," outside of which they are suddenly farther apart again. By studying cod scales at different seasons of the year Dr. Damas concluded that the region where the rings were well separated represented rapid growth under the favourable conditions of summer, and the narrow compressed rings were formed during the winter months. Each band of summer and winter growth together represent one year of the fish's life and the age of the fish can therefore be estimated by counting the number of winter rings on its scales. Fig. 2 shows the margins of successive winter rings on a scale of a four-year-old fish.

In a length frequency curve for the separate ages drawn after determining the age of each fish from a study of its scales, an obvious fact to be plainly deduced from this curve is that we have not sufficient data from which to draw satisfactory conclusions as to the most abundant size for any one age. It appears that the year classes overlap one another to a considerable extent, and that the overlapping becomes greater after the fourth year. This shows that growth is slower and more irregular after the fourth year, which is probably the age at which the haddock mature.

We can deduce the following year classes:—

Year.	Lengths in Centimetres.	Average Length of Age.
2	34-41	37·5
3	39-47	43
4	41-51	46
5	51-58	54·5
6	47-66	56·5
7	50-68	59
8	56-66	61

Comparing the averages of these classes with the averages deduced from the first length frequency curve (Fig. 3B) we find a striking correspondence in the first four classes.

Class.	Age.	Average from 1st length frequency curve.	Average from curve of separate ages.
1	2	36·5	37·5
2	3	42·5	43
3	4	47·5	46
4	5	54	54·5
5	6	61	56·5
6	7	67·5	59
7	8	....	61

Assuming that the scales grow as the fish itself grows, we naturally conclude that the growth of the scale bears a definite proportional relation to the growth of the body. We can thus calculate the amount of the fish's growth each year by measuring the distances between successive winter rings on the scale. The following simple method was used to estimate the rate of growth of the fish from the scales. Two scales from each fish were taken and the margins of the winter rings of each drawn with the camera lucida. The centres of scales were placed to coincide in the figure and their long axes to lie approximately at right angles. A line of a length proportional to that length of the fish from which the scales were taken was ruled between the axes of the scales, and its end joined by straight lines to the ends of these. Parallel to these last lines others were drawn from the points where the winter rings cut the axes of the scales to the median line, thus dividing it into lengths directly proportional to the lengths of the fish at the end of every winter of its life.

When we compare a length frequency curve for each age using the lengths calculated from the scales by the above method with that for the actual length of fish of known age, we find the range of size is much greater in it, where we are dealing with greater numbers of measurements, but the average lengths agree fairly closely.

Year.	Lengths In Centimetres.		Average Length.	
	From Measured Fish.	From Scale Calculations.	From Measured Fish.	From Scale Calculations.
1	....	8-20	....	13
2	34-41	15-33	37·5	25
3	39-47	24-45	43	36
4	41-51	32-58	46	45
5	51-58	38-62	54·5	52
6	47-66	43-63	56·5	54
7	50-68	48-67	59	57
8	56-66	56-66	61	60

It was intended to determine the length, age and sex of a number of haddock to find what, if any, difference of size there was between the male and female fish. The few results seem to show that the difference of sex is not accompanied by a marked difference in length. The following table shows the average size for each year as calculated from the scales of twenty-two fish:—

Year.	Average Length.		Average Length of 74 Fish of both Sexes.
	Male.	Female.	
1	13·5	12·5	13
2	27·5	23·5	25
3	39	34·5	36
4	43·5	43·5	45
5	47·5	49·5	52
6	50·5	52·5	54
7	54·5	54	57
8	59	56	60

The rate of growth curve shown in Fig. 1 is made from the average yearly lengths as determined from the scales of seventy-four haddock. This curve shows a

rapid and practically constant increase in size up to the fourth year. The growth after the fourth winter is slower than in the previous years, and after the fifth winter the yearly increment is very slight. Here we have evidence that the haddock mature in the fourth or fifth year of their life, as growth is probably arrested when the fish begin to spawn.

(D) ASCERTAINED WEIGHTS OF FISH, AND OF CERTAIN ORGANS.

The fish were weighed "round," that is before splitting and cleaning. The balance used weighed accurately to five grammes. The weights showed considerable variation, fish of the same length sometimes differing in weight by more than a hundred grammes.

The livers were weighed without the gall-bladder, immediately after removal from the fish. The percentage of liver-weight to body-weight varied from ·68 per cent to 4·30 per cent; the average percentage for twenty-two fish was 2·25 per cent. We might note that of the two extremes the fish with the smallest percentage of liver was 6 years old and measured 62 cm.; while that with the largest liver was 7 years old and 65 cm. long.

The gonads were weighed as soon as removed and graphs drawn showing the average weights of the gonads for each age. The ovary is proportionately much heavier than the testis except in the four-year-old fish, where average weights of the gonads are equal. The variation in the per cent weight of the ovaries is very slight, there being a difference of only three-quarters of 1 per cent between the largest and the smallest ovary.

(E) SIZE OF EGGS IN THE DEVELOPING OVARIES.

Eggs were taken from the ovaries (at a point beside the junction of the two organs). They were measured with an eyepiece micrometer. The average size of the largest eggs in the ovary was recorded. In general the eggs were ·20 mm. in diameter. In the case of a small 3-year-old fish, the largest eggs were only ·15 mm. in diameter. One 4-year old, and some 6- and 7-year-old fish showed eggs ·25 mm. in diameter. The size of the eggs bears no apparent relation to the size of the ovaries. A very small ovary may contain larger eggs than a larger ovary. From this we see that the size of the egg is probably the best criterion of the state of development of the ovary.

TABLE showing lengths of fish at different ages as calculated from the distance apart of the winter rings.

No.	Sex.	1 year.	2 yrs.	3 yrs.	4 yrs.	5 yrs.	6 yrs.	7 yrs.	8 yrs.	Length of fish when caught.
		cm.	cm.	cm.	cm.	cm.	cm.	cm.	cm.	cm.
1		14	21	36	44·5	51				53
2		13	23	32·5	40	49	54			56·5
3		10·5	23·5	35	41					41
4		16	23	40						43
5		13·5	26·5	34·5	41	49	55	61		61
6		17·5	29	40	45	51				51
7		13	25	34	40·5	48·5	53			52·5
8		9·5	26	40·5						42·5
9		19·5	32·5	39						39
10		20	33	40·5						40.5
11		12	20·5	31·5	41	49·5	54	58		58
12		9	17	27	34·5	44·5	52			55
13		11·5	22	39·5	51	58	62			62
14		10·5	18	29·5	37	43·5	46	52·5	58	60
15		14	28	39	50	54·5	58			62
16		10·5	24·5	33	38	46·5	54·5	60·5	63·5	66
17		17	30	35	41	47	53	51		61
18		15·5	25·5	40·5	50·5	57·5	62·5			66
19		11·5	19·5	29·5	31·5	43	51·5	57·5		60
20		13·5	28·5	39·5	50·5	55				55
21		16	24·5	33	39·5	46	49	51·5		53
22		13	19	27	36·5	45	50·5			51
23		11	20·5	35·5	44					47
24		17·5	31·5	43						46
25		14	27	39	47					49
26		13·5	25	33·5	44·5	52·5	58·5	62		65
27		15·5	27	36	46	56·5	63	67		67
28		13·5	25·5	34·5	46	55	58·5			60
29		12·5	28	42						44
30		12	26·5	36·5	44	51	56	60		62
31		10·5	21	30·5	43	49	54			54
32		9·5	19	27·5	35	46	52			52
33		15	26·5	40	48	54	59·5			62
34		11·5	20 5	29·5	37	42·5	47			47
35		11	26 5	32	47	52·5	57			57
36		12	27	34·5	42·5	28·5	54			54
37		9·5	27	42	47	49·5	54	59	62	62
38		10·5	22	33	41	46·5	52·5			55
39		12·5	26	44	57·5					63
40		13	25	40	49	56	63			63
41		12	25	38	46·5	53·5				56
42		11	27	37	45·5	50·5	56·5	62·5	66	69
43		14	32·5							34
44		13	26·5	39·5	49·5	55				58
45		14	25	36·5						39
46		17	31·5	44						47
52		11·5	22	30	43	54·5	62	66		66
53		11	24·5	38	48	53·5	58			58
54		14	23	32	40	46	51	57		57
55		11	23	31	38	44·5	50·5	53		53
56		13	19	29	35·5	40·5	45 5	52	58	58
57		9	22·5	36	41	46·5	52	57	62	62
145	♂	14	26	34	39·5	45	50·5	55		59
146	♀	14·5	25	40	49·5	54				56
147	♀	11·5	24	33·5	41·5	48	52·5			54
148	♀	10·5	19·5	25·5	37	40	50			52
149	♀	14·5	30	45						47
150	♂	13	28·5	41	47·5					51
151	♂	11	22·5	36	40	46	51	56	59	62
152	♀	9·5	23	37	46	51	54·5			57
153	♀	13	25·5	30·5	37	42·5	47·5	52		53
154	♀	9·5	7·5	24	37	48	53			53
155	♂	15·5	26·5	37	47·5	53				54

TABLE showing lengths of fish at different ages as calculated from the distance apart of the winter rings—*Concluded.*

No.	Sex.	1 year.	2 yrs.	3 yrs.	4 yrs.	5 yrs.	6 yrs.	7 yrs.	8 yrs.	Length of fish when caught.
		cm.	cm.	cm.	cm.	cm.	cm.	cm.	cm.	cm.
156	♀	10	16	26·5	33	37·5	43	47·5	....	50
157	♀	11	25·5	39	51	57·5	62	....	....	62
158	♂	15	30	40	43	46 5	50	53	....	55
159	♀	17·5	30	41	51	55	60	65	....	65
160	♀	13	27·5	38	47	53	....	....	....	53
161	♀	10	17·5	27·5	34	41	49	52	56	56
162	♀	8	15	27	40	50	54	....	....	54
163	♀	16·5	28	44	55·5	62	....	....	....	62
164	♀	17	31	40	47	....	....	....	....	47
165	♀	11	20	32	....	....	....	....	....	39
166	♂	15	31	45	....	....	....	....	....	45

Fig. 1

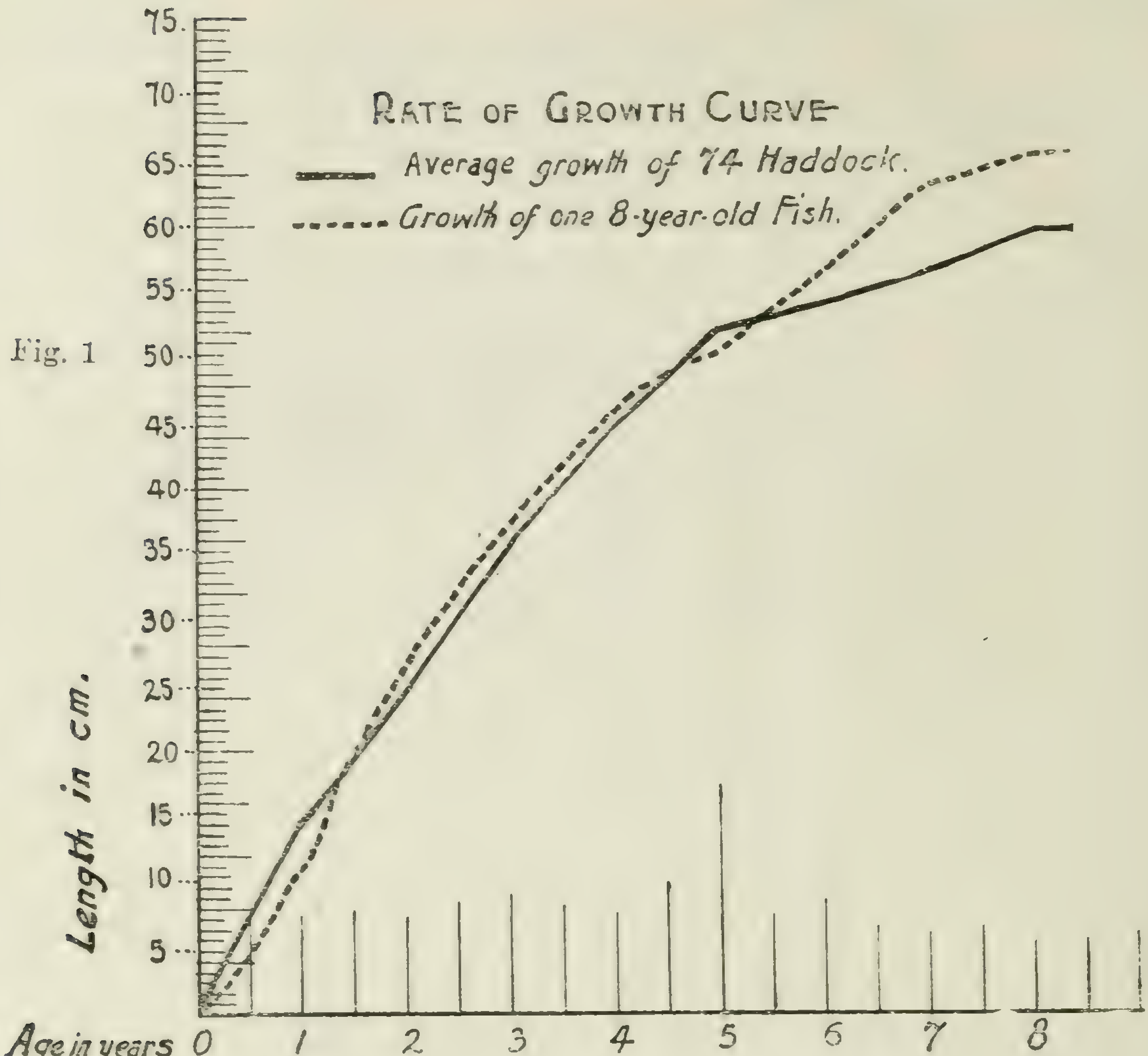


Fig. 2.

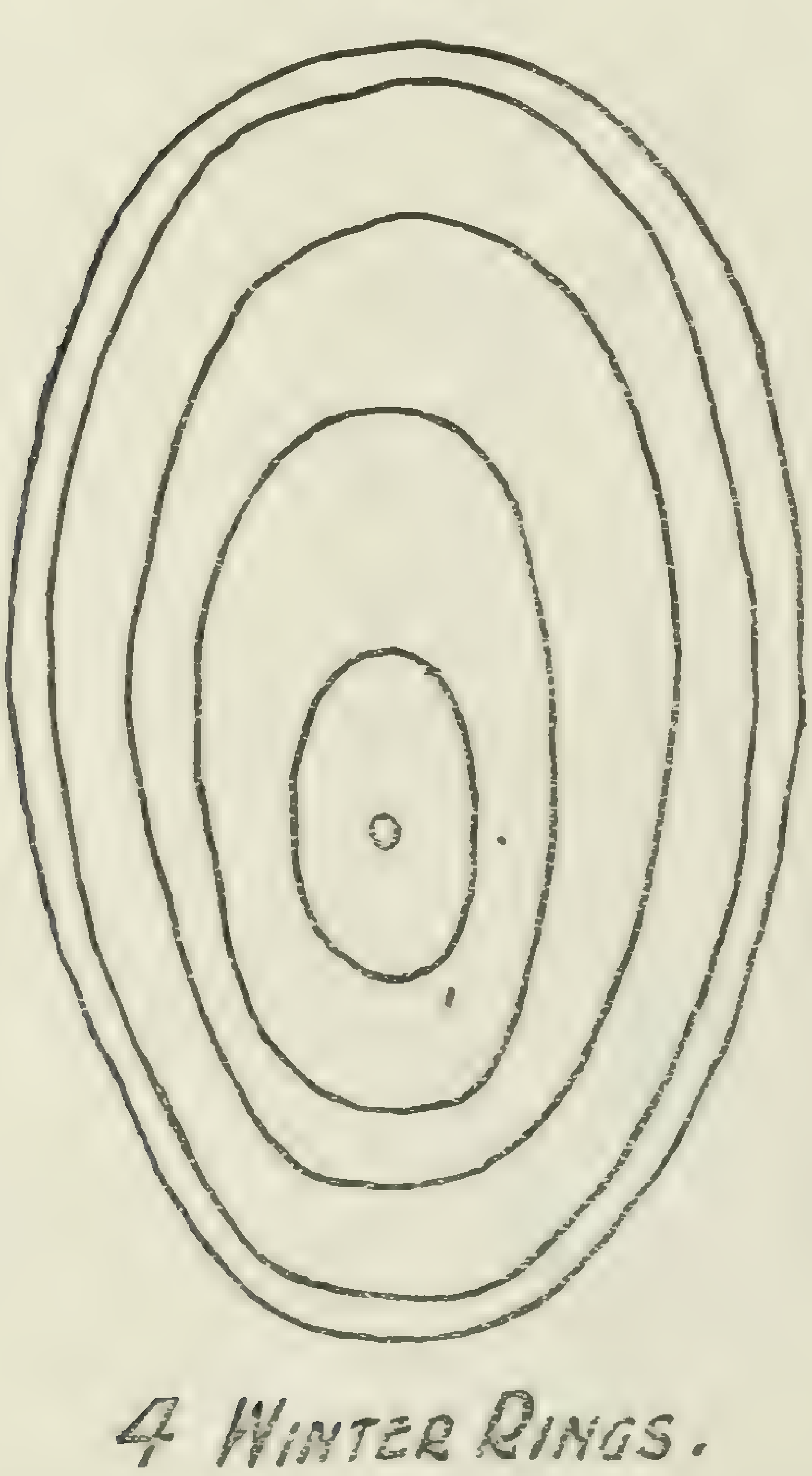
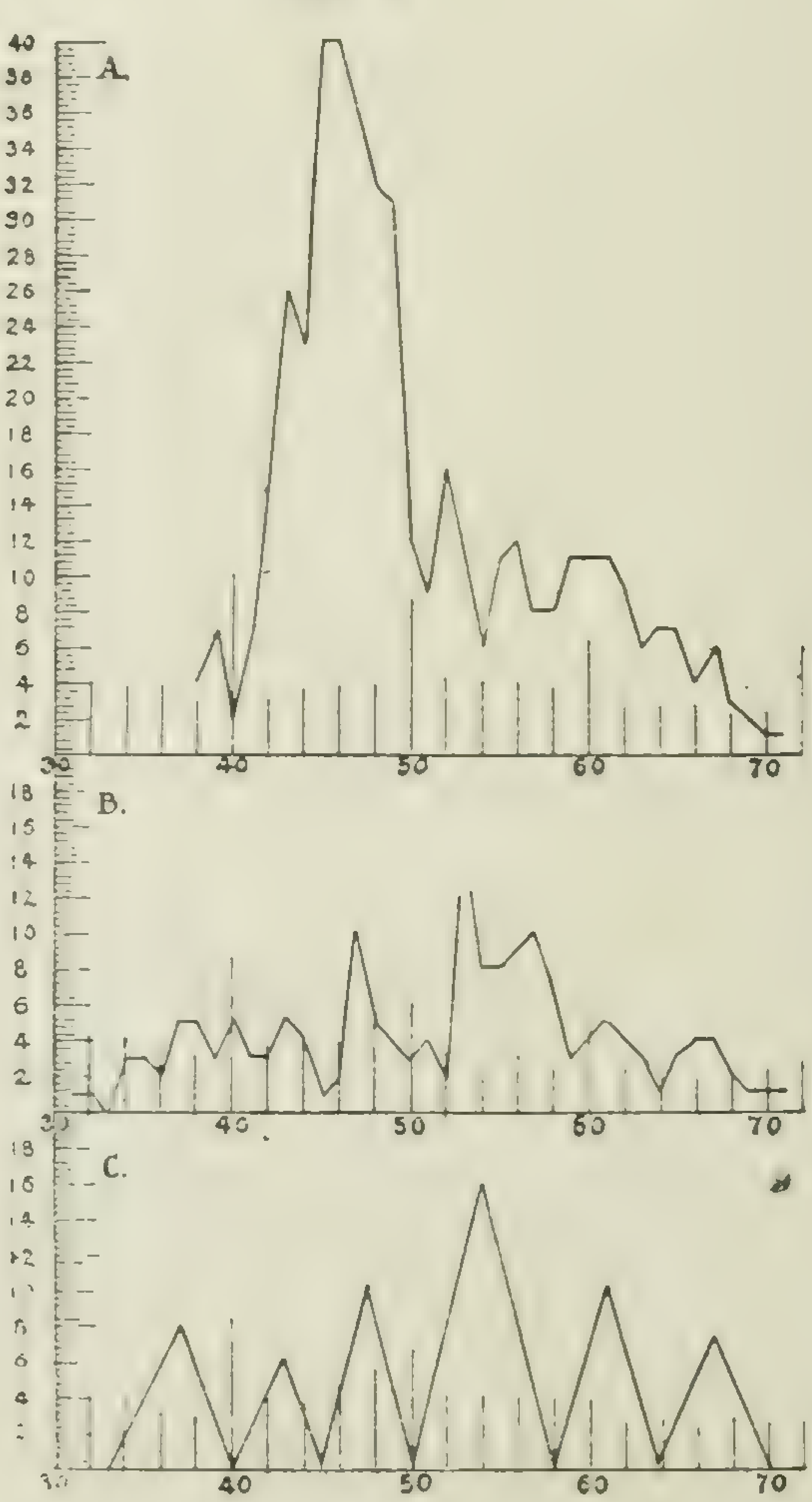


Fig. 3



X

REPORT ON THE LIFE HISTORY OF THE COD AS DETERMINED FROM THE SCALES AND OTHER DATA.

By R. P. Wodehouse, B.A., *University of Toronto.*

This investigation was carried out in the summer of 1914 at the Marine Biology Station, St. Andrews, from the beginning of June till the beginning of September, the object being to test the method of determining the age of a cod (*Gadus callarias*) from its scales, to determine the rate of growth of the cod in these regions (Passamaquoddy bay), and the comparative frequencies of the different "year-classes" and of the different "length-classes." Knowing these facts and the relation between the weights and lengths, it is possible to decide at what age it is most profitable to kill the fish. Recent experiments and the experience of fishermen, in injudicious exploitation of their stock, show that though the sea seems limitless, the stock of fish is by no means inexhaustible. The tagging experiments of Hjort and others show that the annual catch represents a very considerable proportion of the whole stock. In most of these experiments rarely less than 20 per cent of the tags were recovered, and usually considerably more, and it is reasonable to suppose that the number of tags recovered bears about the same relation to the number of fish tagged as the total number caught does to total stock in the sea.

Before proceeding to the results obtained, it will be necessary to explain the method of investigation. The greater number of measurements were taken at Gardiner and Doon's fish market, St. Andrews. The firm were cordial and kindly in allowing us to go there and examine their fish whenever they had the kinds we wanted, and were always ready in proffering information as to the locality and method of making the catches. Two members of the staff of the Station co-worked, one to take the notes and the other to make the measurements and take the scales. The cod were selected as nearly at random as possible, laid on a board and measured with a centrimetre rule, and the length called out to the man keeping notes.

The method of measuring was found to be slow and awkward, so a measuring board was devised on which the fish could be laid and the measurement read off at once. The fish were always measured from the tip of the snout to the end of the vertebral column, reading to the nearest centimetre. It was while on this measuring board that the scales were removed, these (with few exceptions) being taken from the shoulder (usually the right) above the lateral line, forward of the first dorsal fin. The slime and loose scales were carefully removed from the part of the body from which the scales were to be taken, then a few scales (about 50 to 100) were removed with a clean scalpel and placed on a small piece of paper on which the number and length of the fish were marked by the note-keeper. The papers were then folded once and put in the back of the note-book until we returned to the laboratory, when they were allowed to dry until needed for mounting.

In the laboratory the scales so obtained were removed from the papers on which they were collected and soaked in water. There is always a great deal of slime, dirt, and pigmented epidermis, that must be removed. The method found quickest and most satisfactory by the author was as follows: After the scales had soaked for from one to three days in fresh water, the water was poured off and replaced with a weak solution of KOH (about 1:4) in water. The scales must be very carefully watched

in this solution, for if left too long they fall to pieces and sometimes even completely dissolve. The time varies greatly with the saturation of the solution and the condition of the scales, depending largely on the amount of previous soaking in water. They were next washed in three changes of water, which should remove all the slime and dirt as well as the KOH. They are next transferred to 95 per cent alcohol, in which they need only remain a few minutes, when they may be mounted on slides. If the scales are of a fair size, it is best, at this stage, to look at them with a binocular microscope and pick out the best, for always a proportion of them are injured and are not good for age-determination. The alcohol next is drained off and they are placed on miscroscopic slides, ten to twenty from each fish. But if the scales are small, as is often the case, and there are a great many to be studied, it is most convenient to float them on the slide and drain off the alcohol. Before the scales become dry enough to curl up, another slide, lightly smeared with glue at the ends should be placed over them and firmly held there until the glue sets. We found that four spring clothes-pins, clipped on to the two ends, served this purpose admirably. When the glue is set, which usually takes several days in the New Brunswick climate, the scales are ready for microscopic study.

The following is a list of the fish, which (excepting where otherwise stated) were all taken on baited trawls, showing where and when caught:—

North Channel, June 12.

Number.	Length.	Age.	Number.	Length.	Age.
	Cms.	Years.		Cms.	Years.
1	79	4	18	53	3
2	122	6	19	61	3
3	41	3	20	43	
4	123	9	21	64	3
5	98	6	22	60	3
6	78	4	23	55	3
7	54	3	24	52	3
8	48	3	25	68	4
9	41	3	26	41	3
10	60	3	27	50	3
11	46	3	28	55	3
12	60	3	29	47	3
13	37	3	30	55	3
14	29	2	31	42	3
15	35	3	32	39	3
16	51	3	33	56	3
17	50	3			

North Channel, June 15.

Number.	Length.	Age.	Number.	Length.	Age.
	Cms.	Years.		Cms.	Years.
34	44	3	37	76	4
35	59	3	38	54	3
36	61	4			

Bulk Head, June 22.

Number.	Length	Age.	Number.	Length.	Age.
	Cms.	Years.		Cms.	Years.
39	59	3	45	72	4
40	66	4	46	47	3
41	86	5	47	60	3
42	71	4	48	75	5
43	59	3	49	57	3
44	74	4			

Campobello Island, June 23.

Number.	Length.	Age.
	Cms.	Years.
850	35	2

Letite, June 24.

Number.	Length.	Age.	Number	Length.	Age.
	Cms.	Years.		Cms.	Years.
51	47	3	69	43	3
52	44	3	70	45	3
53	49	3	71	33	2
54	36	2	72	36	2
55	42	3	73	103	7
56	37	2	74	83	4
57	34	2	75	43	3
58	41	3	76	58	3
59	36	2	77	57	3
60	36	3	78	65	4
61	44	2	79	50	3
62	37	2	80	41	3
63	34	2	81	43	8
64	38	2	82	39	3
65	40	3	83		
66	35	2	84	44	3
67	34	2	85	43	3
68	33	2			

North Channel, June 24.

Number.	Length.	Age.	Number.	Length.	Age.
	Cms.	Years.		Cms.	Years.
86	60	3	100	53	3
87	52	3	101	53	3
88	63	3	102	43	3
89	49	3	103	87	4
90	66		104		3
91	64	3	105	105	6
92	52	2	106	83	4
93	53	3	107	78	4
94	45	3	108	45	3
95	48	3	109	62	3
96	95	7	110	85	4
97	93	5	111	56	3
98	68	3	112	53	3
99	100				

Mouth of St. Croix River, July 2.

Number.	Length.	Weight.	Age.	Number.	Length.	Weight.	Age.
	Cms.	Grs.	Years.		Cms.	Grs.	Years.
113	38	830	5	116	36	670	2
114	40	850	2	117	37	580	2
115	50	1,840	3	118	33	....	2

Number.	Length.	Age.	Number.	Length.	Age.
	Years.	Cms.		Cms.	Years.
119	33	2	129	111	8
120	31	2	130	65	4
121	17	1	131	57	3
122	33	2	132	94	6
123	34	2	133	68	3
124	33	2	134	56	3
125	29	2	135	70	5
126	33	2	136	44	4
127	103	6	137	57	4
128	132	15	138	92	5

The Reef, July 7.

Number.	Length	Age.	Number.	Length.	Age.
139	35	2	140	37	2

Wilson's Beach, July 16.

Number.	Sex.	Length.	Weight.	Weight Liver.	Weight Gonad.	Age.
		Cms.	Grs,			Years.
141	♂	67	4,200	165	3·17	3
142	♀	53	2,160	55	5·82	3
143	♀	63	2,500	25	12·09	3
144	♂	55	2,160	25	4·76	3
145	♂	50	1,700	25	0·99	4
146	♀	51	1,930	25	5·74	2
147	♀	51	1,700	20	5·03	3
148	♀	44	1,040	15	1·31	2
149	♂	40	750	15	1·37	2
150	♂	47	1,130	30	1·98	2
151	♂	45	1,050	20	1·07	3
152	♀	118	24,110	530	270·00	5
153	♂	38	730	15	1·02	2
154	♂	51	1,820	25	1·32	2
155	♂	47	1,700	25	1·13	2

Bocabec River, taken by means of a seine July 3 (alcoholic specimens).

Number.	Length.	Weight.	Age.	Number.	Length.	Weight.	Age.
	Cms.	Grs.	Years.		Cms.	Grs.	Years.
156	4·25	0·65	$\frac{1}{2}$	159	3·55	0·32	$\frac{1}{2}$
157	4·10	0·62	$\frac{1}{2}$	160	3·70	0·39	$\frac{1}{2}$
158	3·00	0·225	$\frac{1}{2}$				

Wilson's Beach, July 30.

Number.	Length.	Weight.	Sex.	Age.	Number.	Length.	Weight.	Sex.	Age.
	Cms.	Grs.				Cms.	Grs.		Years.
161	48	1,580	......	3	171	34	......	♂	2
162	48	1,449	......	3	172	36	......	♂	1
163	48	1,360	......	3	173	36	......	♀	2
164	33	......	♀	2	174	34	......	♀	2
165	36	......	♀	2	175	30	......	♂	2
166	37	......	♂	1	176	33	......	♀	2
167	35	......	♂	1	177	33	......	♂	2
168	33	......	♂	2	178	36	......	♂	2
169	34	......	♀	2					
170	34	......	♂	2					

Measurements only of Fish caught inside of the Wolves, August 7.

Number.	Length.	Number.	Length.	Number.	Length.	Number.	Length.
	Cms.		Cms.		Cms.		Cms.
179	59	212	44	245	51	278	49
180	46	213	52	246	48	279	53
181	43	214	67	247	45	280	46
182	46	215	46	248	48	281	47
183	48	216	46	249	50	282	45
184	54	217	71	250	47	283	47
185	66	218	45	251	49	284	55
186	53	219	49	252	46	285	47
187	61	220	52	253	47	286	47
188	46	221	49	254	44	287	61
189	52	222	63	255	49	288	48
190	51	223	46	256	49	289	49
191	56	224	51	257	47	290	62
192	55	225	48	258	46	291	45
193	46	226	56	259	46	292	65
194	64	227	53	260	49	293	45
195	48	228	60	261	50	294	44
196	49	229	44	262	52	295	48
197	44	230	63	263	62	296	49
198	47	231	59	264	54	297	51
199	46	232	51	265	49	298	55
200	67	233	52	266	59	299	50
201	47	234	47	267	59	300	56
202	46	235	46	268	61	301	50
203	51	236	50	269	56	302	50
204	75	237	51	270	48	303	53
205	51	238	64	271	55	204	46
206	64	239	56	272	53	305	56
207	59	240	50	273	44	306	55
208	50	241	49	274	56·5	307	55
209	93	242	47	275	54·5	308	47
210	55	243	49	276	51	309	51
211	48	244	47	277	55	310	52

Fish Market, St. Andrews, August 8.

Number.	Length.	Age.	Number.	Length.	Age.
	Cms.	Years.		Cms.	Years.
311	61		342	56	3
312	54		343	60	3
313	59		344	49	3
314	56		345	75	4
315	69		346	54	3
316	53		347	51	3
317	48		348	70	4
318	49		349	48	3
319	63		350	62	4
320	54		351	58	3
321	53		352	51	3
322	61	2	353	49	3
323	46	3	354	50	3
324	61	4	355	56	
325	62	3	356	49	4
326	53	2	357	45	3
327	55	2	358	52	
328	64	2	359	52	
329	57	2	360	48	
330	55	3	361	46	
331	59	3	362	59	
332	46		363	51	
333	52	2	364	55	
334	67	3	365	82	
335	58	3	366	50	
336	108	5	367	52	
337	91	4	368	54	
338	59	4	369	48	
339	54	3	370	49	
340	55	3	371	49	
341	46	3	372	49	

Brandy Cove, August 12.

Number	Length.	Age.	Number.	Length.	Age.
	Cms.	Years.		Cms.	Years.
373	8·0	$\frac{1}{2}$	377	6·2	$\frac{1}{2}$
374	7·8	$\frac{1}{2}$	378	8·6	$\frac{1}{2}$
375	6·2	$\frac{1}{2}$	379	8·5	$\frac{1}{2}$
376	8·0	$\frac{1}{2}$	380	7·6	$\frac{1}{2}$

To bring out the significance of the results contained in these tables, length-frequency curves were plotted. At first all the fish were plotted on one large graph as they were measured, but as the season advanced and new fish were added to the graph, it was found that the curve lost what little form it originally had. This was doubtless due to the increase in length of the fish as the season advanced, throwing them out of their classes. Hence this method was abandoned and only measurements from catches, comparatively close together in time, were plotted on a single graph. This curve was interesting in that the two catches were taken at practically the same time, and the bulk of the fish fall within comparatively narrow limits in regard to length; two shorter and several much longer fish were omitted from the graph. This curve seemed to show that the details in the contour of the curve are meaningless, for the high places in one fill up the low places in the other, so that the sum does not resemble the curve for either of the catches in detail. It appeared also that most of the fish fall within the three-year class (the average length of fish

in the summer of their fourth year, i.e., three-year class, being determined from the other curves to be mentioned later. All the fish except those in the last humps (66 to 71) may be safely taken as 3-year-olds. Another curve was plotted for all the fish caught between June 11 and 24. This showed only a slight indication of division into year-classes. Most of the remaining fish (those caught in July and August) were plotted in another graph. The interesting things about this curve were the way the little fish (which were afterwards found to be less than one year old) fell into two groups representing two different catches taken about five weeks apart. The averages of these two humps indicate a growth of 3·6 centimetres in that time. The one year class is represented by only one fish and the two and three year classes can easily be distinguished.

Since the value of the next part of this paper depends so much upon the age determination of the fish, it will be necessary to explain how the scale is an indicator of the age of the fish. The youngest scale ever observed by me consisted of a single central plate, quite homogeneous, with a single ring of smaller plates around the margin. It was taken from a fish which measured 3·00 cm. The next smallest is from a fish 4·10 cm., and it clearly shows the central plate with three rings of smaller plates around it. From this it seems reasonable to suppose that when the fish starts out in life its scales consist of single plates, and as it grows it adds rings of smaller plates around the central nucleus of each scale. Since the number of scales on the fish does not generally increase throughout life, the linear growth of the scales may be expected to be proportional to the linear growth of the fish. It is found that when the rate of growth of the fish is greater, i.e., in the summer, the plates laid down are slightly larger than those laid down when the rate of growth is less. A glance at any old scale reveals a more or less regular alternation in the open and close bands, in the first three years at least, signifying a regular periodicity in the growth of the fish. It has been demonstrated beyond doubt by other investigators that this periodic retardation and acceleration in the growth of the fish is brought about by the alternation of winter and summer, the close band representing a winter's growth and the open a summer's. Another factor which retards the growth of the fish and consequently leaves a mark on the scale is the spawning period. In some kinds of fish, according to other investigators, the spawning rings can be clearly distinguished on the scales, but in the cod my experience has been that they only lead to confusion between winter and summer rings, making it almost impossible to tell with any degree of certainty the age of the older fish that have spawned many times. Doubtless there are other things which affect the growth of a fish besides the seasons and spawning periods and consequently the markings on the scales; for example, scarcity of food, or temporary incapacity of the fish to obtain food. Indeed I have seen some cod scales in which it was practically impossible to notice any distinction between summer and winter rings, and others in which there appeared to be more winter rings than would be expected from the size of the fish.

In spite of this drawback in the method, the ages of nearly all the fish from which scales were taken were determined and are appended in the tables above. In order to appreciate the significance of the age in relation to the length, the fish were plotted again in their different year classes. This showed that the majority of fish caught for commercial purposes are between two and four years old, and that the greater number of them fall into the three-year class.

In taking measurements for cod very few opportunities are offered for determining the sex. Those that were taken are shown in the tables and use made of them in constructing the rate of growth curves.

To further test the assumption that the rate of growth of the scale was proportional to the rate of growth of the fish, the following construction was made: A scale was drawn with the camera lucida. From the centre of the scale, *A*, a line was drawn to the periphery, *B*, usually in the direction of the long axis of the scale. Another

line, AC, was drawn from the centre of the scale making an acute angle with the first, and of a length which would represent the length (on some convenient scale, usually 1:10) of the fish from which the scale was taken. A line was then drawn connecting B and C and a series of lines were drawn parallel to BC from the points of intersection of the line AB with the rings on the scale. The growth of the fish which would correspond to any of the winter rings would then be read off on the line AC. According to this, the fish, which it is demonstrated was 17 cm. long at the end of the first year, 35 at the end of the second, 53 at the end of the third, 68 at the end of the fourth, and 80 at the end of the fifth, while it was 86 cm. long when caught.

The ages of all the fish whose scales were taken were calculated in this way and set down in table I. In every case two scales were used and unless the determinations from the two agreed, or nearly so, as in the figure, other pairs were taken until two were found that did agree. When all these were averaged up, it was found that the average sizes for a codfish were:—

First year, length, 14·5 cm.
Second year, length, 35·9 cm.
Third year, length, 49·8 cm.
Fourth year, length, 64·9 cm.
Fifth year, length, 82·0 cm.
Sixth year, length, 90·5 cm.
Seventh year, length, 99·3 cm.
Eight year, length, 115·0 cm.

Of the older ones we had too few samples to yield strictly correct results.

The length frequencies of the age classes calculated from the scales of all the fish in which these could be done satisfactorily were also plotted. The older ones and a good many of the younger ones were omitted owing to the difficulty of applying this method to any but the very clearest scales. For the sake of comparison another curve was made in exactly the same way including only Nos. 1 to 112, i.e., only fish caught between June 11 and 24. Since the curves, calculated on the assumption that the growth of the scale of the fish is proportional to the growth of the fish, tell the same story as the curves based on actual measurement of fish, the growth of the scale must be proportional to that of the fish.

The most casual study of the tables and graphs prepared showed that the rates of growth for the individual fishes vary widely, so that scarcely any two fish have the same life history in this respect. Nevertheless it is possible to obtain an average rate of growth for the given locality. This was done, using the averages obtained from the calculated lengths. Separate curves for males and females were plotted, and though not much importance must be attached to them, they seemed to show that the females grow faster than the males during the first two years, and then suddenly their rate of growth falls off so that the curves cross between second and third years. If the relative proportion of males to females varied in the different year-classes, it is quite possible this might account for the irregular features in the graphs studied.

TABLE I.—Lengths of measured cod in the different years of their lives as calculated from the positions of the winter rings by the method described in the text.

No.	Length 1st yr.	Length 2nd yr.	Length 3rd yr.	Length 4th yr.	Length 5th yr.	Length 6th yr.	Length 7th yr.	Length 8th yr.	Length 9th yr.
1	20	40	60	79					
2	18	40	65	96	110	122			
3	11	29	41						
4	18	34	40	71	86	100	112	122	133
5	22	48	65	80	90	98			
6									
7	17	35	51	54					
8	16	32	45	48					
9	11	28	39	41					
10	20	45	58	60					
11	16	30	43	46					
12	15	(?)	(?)	60					
13	20	36	37						
14									
15	15	(?)	35						
16	19	33	47	51					
17	14	33	47	50					
18	20	35	47	53					
19									
20									
21									
22	18	42	56	60					
23	13	38	52	55					
24	14	33	49	52					
25									
26									
27	17	36	47	50					
28	16	35	50	55					
29	18	33	44	47					
30									
31	16	33	40	42					
32									
33	15	47	54	56					
34	13	30	42	44					
35									
36									
37									
38	16	36	52	54					
39	15	41	56	59					
40	15	37	54	63	66				
41	17	35	53	68	80	86			
42									
43	17	40	57	59					
44	17	44	59	71	74				
45	14	39	55	69	72				
46	13	36	45	47					
47	19	45	54	60					
48									
49	10	35	45	55	57				
50	15	32	45						
51	11	26	45	47					
52	10	22	40	44					
53	17	37	45	49					
54	.20	33	36						
55	11	27	38	42					
56	19	35	37						
57	6	32	34						
58	18	34	36						
59									
60	8	23	32	36					
61	18	41	44						
62	16	30	37						
63	10	34	39						
64	16	35	38						
65	9	25	37	40					

TABLE I.—Lengths of measured cod in the different years of lives, etc.—*Continued.*

No.	Length 1st yr.	Length 2nd yr.	Length 3rd yr.	Length 4th yr.	Length 5th yr.	Length 6th yr.	Length 7th yr.	Length 8th yr.	Length 9th yr.
66	13	33	35						
67	14	31	34						
68	9	30	33						
69	9	28	40	43					
70	7	32	43	45					
71	8	31	33						
72									
73	16	28	47	63	77	88	103		
74	25	51	66	76	83				
75	6	23	41	43					
76	10	36	54	58					
77									
78									
79	14	34	47	50					
80	8	24	38	41					
81	11	26	41	43					
82	8	23	37	39					
83									
84	7	23	42	44					
85	9	24	39	43					
86									
87									
88	15	39	60	63					
89									
90									
91	22	44	52						
92	26	47	52	64					
93	20	41	51	53					
94	12	30	41	45					
95	9	25	42	48					
96	17	34	45	61	71	81	91	95	
97	15	37	53	76	90	93			
98	23	49	62	68					
99									
100	14	36	47	53					
101	19	37	49	53					
102	9	31	41	43					
103	20	44	69	83	87				
104	30	70	95	100	(?)				
105									
106	26	52	72	81	83				
107	24	44	60	74	78				
108	15	30	42	45					
109	10	31	58	62					
110	20	43	68	81	85				
111	18	37	51	56					
112	14	37	49	53					
113									
114	17	38	40						
115	16	03	47	50					
116	13	33	36						
117	15	32	34						
118									
119									
120	9	28	31						
121	11	17							
122	13	27	33						
123	11	31	34						
124	18	31	33						
125	13	26	29						
126									
127	23	46	57	76	87	98	103		
128	12	32	44	56	71	85	95	108	111
129									
130	18	39	39	53	62	65			
131	24	46	57						
132	15		53	66	82	91	94		

TABLE I.—Lengths of measured cod in the different years of lives, etc.—*Concluded.*

No.	Length 1st yr.	Length 2nd yr.	Length 3rd yr.	Length 4th yr.	Length 5th yr.	Length 6th yr.	Length 7th yr.	Length 8th yr.	Length 9th yr.
133	22	41	65	68					
134	15	32	47	56					
135	13	29	43	58	66	70			
136	6	22	30	40	44				
137	14	31	43	53	57				
138	28	50	62	78	87	92			
139	15	32	35						
140	16	34	37						
141	20	42	60	67					
142	17	37	49	53					
143	15	39	58	63					
144	20	37	53	55					
145	14	27	41	48	50				
146	16	45	51						
147	15	38	47	51					
148	17	40	44						
149	17	35	40						
150	11	33	47						
151	10	28	42	45					
152									
153	16	36	38						
330	18	37	49	55					
331									
332									
333	20	45	52						
334	10	46	61	67					
335	14	30	54	64					
336									
337	20	54	71	86	91				
338	13	33	45	55	59				
339	12	32	49	59					
340	21	39	53	55					
341	13	34	45	49					
342	20	41	53	56					
343	17	40	56	60					
344	10	26	43	49					
345	17	42	56	64	70	75			
346	13	35	50	54					
347	13	30	46	51					
348	22	45	61	67	70				
349	9	22	43	48					
350	16	40	49	56	62				
351	22	38	49	58					
352	15	31	48	51					
353	16	44	49						
354									
355									
356									
357	14	30	42	45					
358									
359									
Average	14·5	35·9	49·8	64·9	82	90·5	99·3	115	

XI.

ARE MIGRATING EELS DETERRED BY A RANGE OF LIGHTS—REPORT ON EXPERIMENTAL TESTS.

By Prof. Philip Cox, Ph. D., etc., *University of New Brunswick.*

Some one had ventured the opinion, on what grounds I know not, that such a device is effectual, and I was requested to test it by a series of experiments at the Biological Station, St. Andrews, in the summer of 1913. As the common eel, *Anguilla chrysopa,* is known to be a persistent and voracious spawn-eater, its exclusion by any means from the spawning grounds of lake and river food-fishes would be of vast importance to those fisheries, and give a stimulus to the restocking of new or depleted waters.

No fact is better known to the small boy who builds his fire at the water's edge after night, than that eels are attracted by the light; but will they come fully into and pass through it?

Two series of experiments were conducted: the first, in one of the tanks in the laboratory; the second on a larger scale and under more normal conditions in the outlook of Bocabec lake, 12 miles from the station.

Experiment I, July 27.—In a tray, 7 feet by 3 feet and 3 inches deep, were placed five eels which had been taken from a fresh-water lake, and gradually passed through water of increasing degrees of salinity until the average was reached. Water was admitted through a tap, provided with a jet attachment, and the stream struck the surface at a very acute angle, keeping the tray well oxygenated. Across the tank, and resting on the sides 2½ feet from the upper end, was a broad board on which an acetylene lamp stood, screened behind so that the lower part was dark, the other brightly lighted, and the line of demarcation between the two sharp and well defined. It was remarkable how soon the fish seemed to accommodate themselves to the increasingly salt medium, which at first made them apparently very uncomfortable but at the end of two or three hours failed to have any apparent disturbing effect at all. One fish, a very large one, had been in the tray two days before the experiment began; the rest were placed there in the afternoon of the evening when the first trial was made.

July 27.

Experiment I.

At 9 p.m. the fish were screened to the lower end of the tray, the laboratory darkened and the lamp lighted.

9.26. An eel moved into the light, swam to the end of the illuminated space, turned and disappeared in darkness. This was the large one which had been imprisoned two days.

9.30. Another moved half-way into the light and rested there.

9.36. It swam out into the lighted area, turned, stopped for a minute or two, and disappeared.

10.50. One has pushed its nose to the illuminated line.

10.52. It dropped back into darkness.

11.30. Another, the large one, has drawn up close to the lighted line.

11.45. Another has moved up to the same place.

12.00. The former has moved into the lighted space. raises its muzzle above the surface, and then swims back into darkness.
12.18. The same fish returns into the light, raises its nose above the water, and remains motionless.
12.23. It returns to the shadow.
12.35. A small individual has passed into the light.
12.38. It returns to darkness.
12.45. Another has gone into the light.
12.48. It returns to the shadow.

July 28.

Experiment II.

10.10 p.m. Lamp lighted and room darkened.
10.15. Big eel has gone into the light.
10.55. Returns to darkness when a more intense light was made.
11.00. The same fish has moved into the light.
11.15. Has returned to darkness.
11.25. The same one has returned, but only head in the light.
11.36. It passes fully into the light.
11.50. Returns into the shadow.
12.05. Extinguished light.
12.10. Turned on the light suddenly. One was in upper part of tray, and the others that had remained most of the evening in the lower part had moved far up.

Several evenings were devoted to the observation of these fish, but their actions and movements were quite similar to those recorded above, except that the longer they were kept in confinement, the less they seemed to avoid the light.

It was thought that more satisfactory results could be obtained by conducting the experiments under more natural conditions, and for this purpose the outlet of lake Bocabec was chosen. It was admirably suited for the purpose, flowing through a level little valley, had a smooth clay and sandy bottom, water from 5 to 7 inches deep, with a gentle current, and banks regular, grassy, and slightly undermined, here and there affording a cool retreat for the eels during the day.

Two wire screens about 10 rods apart were stretched over the stream, there about 12 feet wide, and sunk some inches into the bottom and banks to prevent the eels from escaping by borrowing.

Two large bullseye lanterns were arranged, one on each side at the level of the water directly opposite and facing each other. The arrangement made rendered it impossible for a fish to pass without being seen by the observer.

Seven large eels were got from a fisherman who had caught them in a herring weir that day, and were placed in the pond just before noon hour, August 15. They showed the effects of a sudden change from salt to fresh water in a more marked manner than the first lot did on being transferred from a fresh to a brackish medium. Restlessness, rapid breathing, gasping, swimming from one end of the enclosure to the other, seeking to surmount the barrier, wheeling and moving rapidly to the other end, opening the mouth widely and swelling the gill region to a marked degree; all these symptoms continued with gradually lessening intensity until about 6 p.m., when most of them were quieter and breathed more moderately and regularly. During that afternoon and next day, they showed no tendency to huddle or seek concealment, but lay out in the open stream, one here and one there, but on the third day they were active in seeking hiding places and huddled. It would seem as if the open free life is the natural one to these large fish, but it is probably otherwise with smaller ones, though young ones from 5 to 7 cm. in length will swarm up an inlet from the sea all day under direct sunlight.

Late in the evening when it begins to grow dark, they become very active, issuing from their retreats, and heading up stream, one by one.

All the eels were driven below the line of the lamps, and the latter lighted at 8.45.

Experiment III.

9.45. One ran past, but manifesting uneasiness returned to darkness a minute or two later. I should have observed that the lights were only about 6 feet below the upper screen, hence the intervening space was fairly well lighted up, but planks across just below, made a marked line of division between the two.
10.00 Another runs past, but returns almost immediately.
10.20. Another passes the light but goes back into the shadow at once.
10.30. Another acts in a similar manner.
11.10. One passes; three or four lying just below the line of light, but they soon drew back.
11.30. Another ran by.
11.40. Another ran by.
11.50. Another ran by.

All of these soon returned to darkness. During the rest of the vigil an hour or more, the fish as a whole lay in darkness, and, though restless and active, avoided the light.

In a general way they repeated the movements of those observed in the trays—approached the light cautiously, lay motionless for some time just below the lighted line, then passed into and through the lighted area. It was not until the third night that any rested more than a few minutes in the light.

Though the fish were about the same size and could not be distinguished one from another, the above record would seem to point to the majority or all of them having passed the range of lamps during the night. They were fish fresh from the sea, and their behaviour may be taken as representative of the species under similar conditions, and hence had there been no screen above the lamps they would have all passed and entered the lake. Still it must be noted that these fish had been impounded eight or nine hours before the lamps were lighted, and their experience in the meantime, as well as the painful effects of changed osmotic pressure, may have, on the first night at least, modified their otherwise natural actions. Still their movements the next two nights were very similar; for a failure to secure fresh lots of fish, so late in the summer, obliged the experimenter to use the same fish all the time.

They always evinced a desire to run upstream at nightfall, but after eleven o'clock very few attempted it, contenting themselves with remaining in the darkened area, where they were often heard splashing and moving rapidly about, sometimes trying to surmount the screen, at others twisting and turning violently in the middle of the stream. With the exception of a few fry of the minnow, *Coueslas plumbus* Ag., in the upper or lighted part of the inclosure, there was no food visible except a few weeds here and there.

Before closing the vigil one night, I looked over the lower part to see where the fish were, when one was seen to scud away from the light of my lantern, which suggested the trial of a *moving* light. Next night one was suspended over the middle of the stream, midway between the bullseyes and a little above, and kept swinging crosswise the stream by means of a cord. For two or three hours none ventured to pass, and hope ran high that the problem had been solved. They came up to the line of light beforementioned, and pushing the head just beyond, lay motionless for a half hour or so, as if watching the moving object, then they withdrew, only to repeat the action some minutes later. About midnight, however, one after another gradually drew into the lighted area, until all I had impounded were lying side by side, only a few inches apart. One after the other, curving the anterior half of the body upwards

and resting the other half on the bottom, thrust the head out of the water far enough to expose the muzzle and eyes, and there they remained ogre-like, to an extraordinary degree, and motionless, as if watching intently the moving light. In a few minutes they began to sink back slowly and almost imperceptibly, and withdrew into darkness. Next night, this sigular behaviour was not observed except in one case. The eels paused at the line of light, but after a half hour or so, began to shoot rapidly past and remained in the upper part of the lighted area the rest of the night. Less and less fear of the swinging lamp was manifested night after night, until they seemed to pay little or no attention to it.

It has been remarked that when first put in, the fish showed no schooling tendency, indeed seemed to manifest distrust of one another; but as time passed, they became more social, and would often be seen during the day lying side by side under the overhanging bank. When disturbed they scudded into the stream, stirred up a cloud of mud at one point, when it settled only the head of the eel could be discerned. It was at length seen that the fish buried itself tail first. All the time the water was gradually falling and its temperature rising, and at length the eels ceased to lie by day under the bank, but their heads were to be seen here and there, though barely visible in the mud. Trial was made, and its temperature was found to be several degrees cooler than that of the water—a good reason for the fish burying themselves in it.

It will be seen that these two experiments were conducted under some objectionable conditions:—

(1) The fish were penned, not free.

(2) They had been taken from salt water and put into fresh water or vice versa, without in one case passing through slowly changing degrees of salinity.

(3) The season for migration to fresh water had long passed.

Waiving the modifying influences of these conditions and summing up the results of the tests we see evidence that—

(1) The fish were certainly afraid of the light at night. They would pause on the line of illumination; move slowly until about half the body was exposed, and then hurry past. As a rule, they soon returned to darkness, though after three or four nights experience they would linger a long time in the light.

(2) The longer they were in the pen, the less fear they showed.

(3) The moving light was at first fairly effective, but after a night or two they paid little attention to it.

(4) That they failed to appear except at rare intervals in the illuminated end of the pen after the third night was probably due to a growing consciousness of their being impounded.

All things considered it seeems very unlikely that their ascent could be arrested by such means.

XII.

POSSIBLE LOBSTER PLANTING AREAS ON THE EAST COAST OF VANCOUVER ISLAND, B.C.

By C. McLean Fraser, Ph.D., etc., *Curator, Pacific Coast Biological Station, Departure Bay, B.C.*

(With Map.)

1. Review of Attempts to Plant Lobsters in Pacific Waters.

The idea of successfully transplanting lobsters from the Atlantic coast to the Pacific has been to the fore many times since the first shipment was attempted by the United States Fish Commission in 1873, or since the first successful transportation and planting in the following year. The fisheries of British Columbia did not come into much prominence until later, but when they did, the idea found lodgment among Canadians also, and a first attempt to transplant these crustaceans was made in the summer of 1896. According to the Fisheries Report of that year (pp. 289-291), 600 live lobsters left Halifax on July 2, about 50 per cent of which perished en route. The distribution is reported as follows: "At New Westminster we transferred the whole shipment to the tug provided. We steamed over 100 miles from five o'clock in the morning till nine at night, but could not find the water sufficiently salty anywhere, the whole straits of Georgia being highly coloured with floating sediment from the Fraser river. We put 196 live lobsters, including two very large ones weighing over 10 pounds each, and many females with eggs, on inshore grounds adjacent to Nanaimo lighthouse in charge of Mr. Brown. We put seventy-two near the shore, surrounded by a net. The rest we put overboard in deeper water en route to Nanaimo, hoping that the water would be more salty near the bottom."

In 1905 a second shipment was brought out, starting from Halifax June 8 (cf. Fisheries Report, p. 285). This consisted of twelve crates containing 590, and eleven barrels or patent carriers containing 435, a total of 1,025, the majority of which arrived safely at Vancouver. Those in the boxes were deposited "in a bay just above the Second Narrows on the south side of Burrard inlet, about 5 miles above Vancouver, the bottom consisting of rocks and kelp." Of the remainder, "one barrel and three berried lobsters were planted in Secret cove, Sechelt peninsula, one barrel and three berried lobstrs in Long bay, southeast corner of Gambier island, one barrel and three berried lobsters in Snug cove, east of Bowen island, three barrels and fifteen berried lobsters in False narrows, four barrels and the remainder of the berried lobsters in Nanoose bay."

The third shipment was made in 1908 (cf. Fisheries Report, p. 271). This consisted of fifteen crates containing 1,620 lobsters, of which "some 1,100 were ultimately placed in the large crates in Sooke harbour and kept there for some weeks, which proved beyond a doubt that this crustacean would live and thrive in Pacific waters. The distribution was subsequently made in various waters."

In the following year, I believe, a number of eggs were hatched out at the Biological station under the supervision of the late Mr. G. W. Taylor and Dr. A. G. Huntsman. The young lobsters were liberated in Departure bay.

2. Apparent Non-success of Lobster Shipments.

Although the United States Fisheries Department has been planting lobsters in the Pacific for over forty years, and the Canadian Department for nearly twenty years, I believe I am correct in saying that there is no record to show whether or not any of these lobsters have survived to spawn and produce another generation. Scores of the reports have been correct, but one is much inclined to doubt it after following up so many of the reports only to find that the so-called lobsters were not lobsters at all. In nine cases out of ten these prove to be sand shrimps, either of the species *Callianassa californensis,* or of the species *Eupogebia pugettensis.* Why is it not possible to find out for certain if the lobsters are present in these waters?

3. Reproduction of Lobster.

According to Herrick[1] the female lobster is 6 or 7 years old when it first spawns. In British Columbia waters there have been about 2,400 lobsters planted. Of these, about 300 were planted in 1895. At most, even if those were old enough to spawn at the time they were planted, there could not be more than three generations since. We have no means of judging as to how many would survive from each batch of eggs, but they would do very well if the number were increased 100 per cent in each generation. In that case there might be 1,200 from the first lot by this time. In 1905 about 1,000 were planted. There would be but time for one generation of lobsters from these, hence on the same basis of calculation there might be 2,000 of these. From those planted in 1908, about 1,100, there might be as many more well grown or perhaps old enough to spawn, making 2,200 in all. Of course, the mature lobsters would keep on spawning, every two years according to Herrick, but even taking that into consideration, the above estimate would probably be high, and this would not make more than 5,000 in all. The distance from Secret cove, Sechelt peninsula, to Sooke harbour, north and south, is approximately 120 miles; the distance from the Second narrows, Burrard inlet, to Nanoose bay, east and west, is about 50 miles. The area between these points would therefore be at least 4,000 or 5,000 square miles. Consequently, if the lobsters have done well, there may be one to each square mile on an average, provided none have moved outside of that area.

4. Migratory Powers of Lobster.

It is true that ordinarily the lobster is sedentary in its habits, and we might expect to find them somewhat massed around the points at which they were planted, but even that would not make them very plentiful in any one locality. On the other hand, from tagging experiments carried out at Wickford[2] we have record of some rather rapid migration. One covered 12 miles in eleven days, another 10 miles in less than eight days, and several others made records almost as good. Since that is the case, if those planted were not in localities to suit their taste, they might have moved off a few miles to find better ones. In this case they might be massed in some locality not so very far away. What chance is there to find such a locality, or if they are scattered what chances are there for any great number to be near the original location? Efforts have been made time and again to locate them by means of lobster pots, but in vain. There is little chance of getting them in such a way except by accident. They should appear in shallow water occasionally, but even if they did, many of the islands are uninhabited or but sparsely inhabited, hence they might be

[1] Herrick, F. H., Natural History of the American Lobster. Bull. U. S. Bureau of Fisheries, vol. XXIX, 1911.

[2] Natural History of the American Lobster, p. 180.

plentiful without being seen. But even if they were seen and possibly if they were recognized, not one in a thousand of those likely to see them would ever report. The chances are all against getting definite information in the matter.

5. Favourable Reports of Results.

The only evidence that appears to be available, as far as the experiments in this province go, is favourable. Of those planted in 1905 in the small bay at Mudge island at the entrance to False narrows, we have direct evidence that they seemed to thrive for a time. They were prevented from escaping by means of a net drawn across the entrance of the bay. The net rotted and was taken away by a storm in a couple of months, but during this time the lobsters seemed to thrive although they had but little room for exercise, especially at low-tide. There was no sign of any dead lobsters and nothing to indicate that they were not in the best of health. Again in 1908 when the shipment was taken to Sooke and the lobsters put in crates, the report already quoted says that they lived for some weeks before they were distributed. But that is not all. Inspector E. G. Taylor has informed me that when the crates themselves were taken away to be broken up, some time later, there was an occasional lobster still present, apparently hale and hearty. In both these cases if the lobsters got along so well for the first few weeks, that there was no evidence of mortality, it would seem that they should get along all right at any time. To this conclusion one objection might be raised. While the lobsters were in the net or in the crates, they were protected from any species that might cause their destruction. When the protection was removed and the lobsters were exposed in the open waters such enemies might appear. As an offset to this it might be remarked that the mature lobster is fairly well able to look after himself, and since other crustaceans, by no means so well provided with weapons of defence, thrive in these waters, there cannot be many enemies that the lobster would need to fear.

6. Bottom, Food and other Conditions.

Comparisons have been made of conditions in the Pacific and in the Atlantic as to the possibilities of or the suitability for lobster rearing. Rathbun[1] has gone into the matter rather fully, but, he has made the comparison chiefly in reference to the San Francisco region, it may be worth while to make a similar comparison with the Vancouver Island region.

In the first place, as to natural resorts, there is no lack of such rocky, gravelly and sandy bottoms, with ample provision of kelp and other large algæ. The area for such at suitable depths in this vicinity will be considered later.

As to food material, Prince[2], in speaking of the American lobster, says: "Lobsters may be almost said to be omnivorous. They are certainly not particular in their diet, and greedily devour fish alive, dead, or even putrid, seaweed, eelgrass (*Zostera*), shrimps, starfish, indeed anything in the nature of edible material." Herrick[3] mentions fish, crustaceans, chiefly isopods and decapods, molluscs, including clams, large and small univalves, echinoderms, including starfish and sea-urchins, hydroids and algæ. British Columbia waters could certainly supply a greatly varied menu along those lines. There are bottom fish of so many species that it is quite probable many of them have not even been examined. There are plenty of dead fish, particularly at certain times of the year, e.g., when the dog salmon start up the streams to spawn. As to Crustaceans, Taylor's list[1] will give some idea of the variety of the decapods.

---

[1] Rathbun, R., Transplanting of Lobsters to the Pacific Coast, Bull. U.S. Fish Commission, vol. VIII for 1888, pp. 453-472.

[2] Prince, E. E., Report of the Canadian Lobster Commission, 1899, p. 9.

[3] History of the American Lobster, pp. 185-187.

Isopods are not so numerous in species but are by no means lacking in number of individuals. As to molluscs, Taylor's papers[2] will indicate very well the number of species and Thompson's[3] papers indicate the extent of the beds of some of the edible forms. If echinoderms serve as toothsome morsels, the lobster may feast at will along this coast. Starfish are so numerous as to be almost a plague; two species of sea-urchins are present in abundance, and, if it will only tackle the holothurians, *Stichopus californicus* should supply him with trepang for many days in the year. The abundance of hydroids in indicated by some of my own papers, particularly the most recent.[4] In many places the sea-bottom is carpeted with them, while around the rocks, piles, etc., at and below low-tide they appear in great quantities. If the lobster enjoys a meal of these as the crab evidently does, it may have them for dessert as often as it wishes. Eel-grass, fucus and kelp are everywhere abundant if it chooses to turn vegetarian. As far as food material is concerned, therefore, there need be no lack.

7. Temperature Conditions in British Columbia Waters.

Another condition on which considerable stress has been laid is the temperature of the water. Although that is the case, there has really been very little ground on which to base a comparison. Rathbun (cf. p. 454) makes the statement: "The continuous temperature observations in the possession of the Fish Commission relate mainly to the surface waters, but in the shallow areas where they were taken there is generally not much difference in this respect between the surface and the bottom." That may be true at the points referred to and yet in the temperature charts for the vicinity of Woods Hole,[5] a difference of 4 degrees or even more is shown in some instances in the very shallow water of Buzzards bay. At present we have not very many readings at various depths for this district but the few we have indicate that it is not safe to make such a statement. As an instance, at a point in Departure bay, which is nowhere much more than 25 fathoms deep, the following readings were taken on July 15, 1914:—

Surface	63·1° F.
1 fathom	61·0° F.
2 "	60·4° F.
3 "	59·5° F.
4 "	57·9° F.
5 "	56·3° F.
10 "	53·8° F.
20 "	51·4° F.
25 "	50·7° F.

A more sudden change was shown on October 14, 1914, when the following readings were obtained:—

Surface	52·9° F.
1 fathom	49·73° F.
2 "	49·46° F.
3 "	49·19° F.
4 "	49·01° F.
5 "	48·83° F.
10 "	48·65° F.
20 "	48·49° F.

[1] Taylór, G. W., B.C. Decaod Crustaceans, Contributions to Canadian Biology, 1906-1910, pp. 187-214.

[2] Taylor, G. W., Preliminary Catalogue of the Marine Mollusca of the Pacific Coast of Canada. Trans. Royal Soc. of Canada, Sec. iv, 1895, pp. 17-100.

Notes on the Marine Mollusca of the Pacific Coast of Canada, Trans. Royal Soc., Sec. iv, 1899, pp. 233-250.

[3] Thompson, W. F., Report of the Commissioner of Fisheries for B.C., 1912, pp. I 7–I 56; 1913, pp. R 103–R 130.

[4] Hydroids of Vancouver Island Region. Trans. of the Royal Society of Canada, Sec. iv, 1914, pp. 99-216.

[5] Sumner, Osburn and Cole, A Biological Survey of the Waters of Woods Hole and Vicinity. Bull. U. S. Bureau of Fisheries, vol. XXXI, 1913, pp. 429-432.

and this at a time when the temperature at the surface was not high. The range here would easily fall within the extremes 32° to 76° as given for the Atlantic waters, for unless for a fathom or two at the surface or on long sloping beaches, it would seem from the little data that we have that the temperature is not likely to go below 45° or above 65° at any depth in the strait of Georgia and the straits and channels among the islands. Moreover, in cases where it is stated that the lobsters live in localities where there may be somewhat extreme surface temperatures, it is commonly stated as well that the lobster migrates to the deeper water to escape the cold of the shallow water. This is only a surmise, however, and not necessarily a correct one, as the migration is just as liable to be due to the necessity of going to deeper water for requisite food material which at this time of year might be scarce in shallow water areas. It has been proved time and again that the lobster seems to be in no way harmed by being kept at a low temperature during transportation, hence if the low temperature alone came into play the winter migration might not be necessary. At any rate there seems to be little doubt but that the lobster can adapt itself to considerable variation in temperature provided it is not too high, and a danger from high temperature is not likely to be a factor in the waters of the strait of Georgia.

I have found that there is very little difference in temperature in water at 100 fathoms or even at 50 fathoms in July and October, hence there is not likely to be very great difference during the rest of the year. I have no data as to the temperature at these depths in the Atlantic, but would be surprised to find that it differed much from the temperature at the same depth here. It would seem, therefore, although we may not have such extremes of surface temperature as in the Atlantic where the lobsters are now at home, yet at the depths that the lobsters are likely to be located at any particular time of the year there is not likely to be very much difference, not enough to be of any serious obstacle to their welfare.

8. Conditions of Density and Salinity of Water.

Another feature to which scarcely any attention has been paid by those who have written about the lobster, viz., density or salinity, would appear to me to be much more important than the temperature and yet from this lack of attention it is impossible to give any satisfactory comparison. Herrick in his large work of over 250 pages does not consider the question at all. Prince says: "Lobsters avoid localities where fresh-water streams run in unmingled with salt water," but that does not help out a great deal. Rathbun does not think it worth mentioning in his comparison. Reports on destiny in two localities on the Atlantic coast where lobsters are found may give some idea of what density is required. In the paper already mentioned on the biological survey of Woods hole (cf. pp. 433-436) four density charts are given for Buzzards bay and Vineyard sound. The water is all so shallow in the area surveyed that it is scarcely comparable to the waters of the east coast of Vancouver island, and yet as lobsters live and thrive in these waters, the degree of salinity must be favourable. The water at the bottom has practically the same density as that at the surface in nearly all cases, with but few instances where the density is lower than 1·0230 or higher than 1·0240, very uniform throughout the year. In a paper on "The Temperatures and Densities of Passamaquoddy bay and its Environs"[1] the density measurements were all made during the summer months and most of them were at the surface or not more than 5 fathoms from the surface. These readings fall fairly well between the same limits as do those at Woods hole, although there is noticeable variation due to the excessive change of the tide. If it is necessary to have a salinity represented by such density right to the surface of the water then it is useless to attempt to grow lobsters along the east coast of Vancouver island, because it would be a difficult matter to find a spot between Haro strait and Queen Charlotte sound

[1] Copeland, G. G. Contributions to Canadian Biology, 1906-1910, pp. 281-294.

at least, where the density is not noticeably lower than this, through a great portion of the year if not through the whole of it. Readings as given in a preliminary paper on density and temperature by Prof A. T. Cameron and myself, which follows this paper, show that during the summer months, when these readings were made, the average surface density within this area falls between 1·0180 and 1·0190. Practically the same thing is true of such large inlets as Barkley sound, into which pour large streams of fresh water. This would indicate that the salinity in the strait of Georgia at the surface is only about 80 per cent that of the salinity at Woods hole or Passamaquoddy bay. On the other hand if it will answer the purpose to have such a density at 10 fathoms or even at 5, and there seems no reason why it should not, as apparently the lobsters are at that depth or more for the greater part of the time, the question is quite a different one, as over a great portion of the area mentioned such a density, in all probability, exists throughout the year. This might account for the fact that the planted lobsters, if any of them do exist, are not seen in shallow water.

9. Enemies of the Lobster.

As to the enemies of the lobster, there are numerous predaceous fish that would enjoy the taste of young lobster, but whether they are more or less abundant, more or less predaceous, than these on the Atlantic coast, it is impossible to know. The chances of the young lobster growing to the adult stage seems as much beset with difficulties in the one case as in the other. A reference to enemies of the full-grown lobster has already been made.

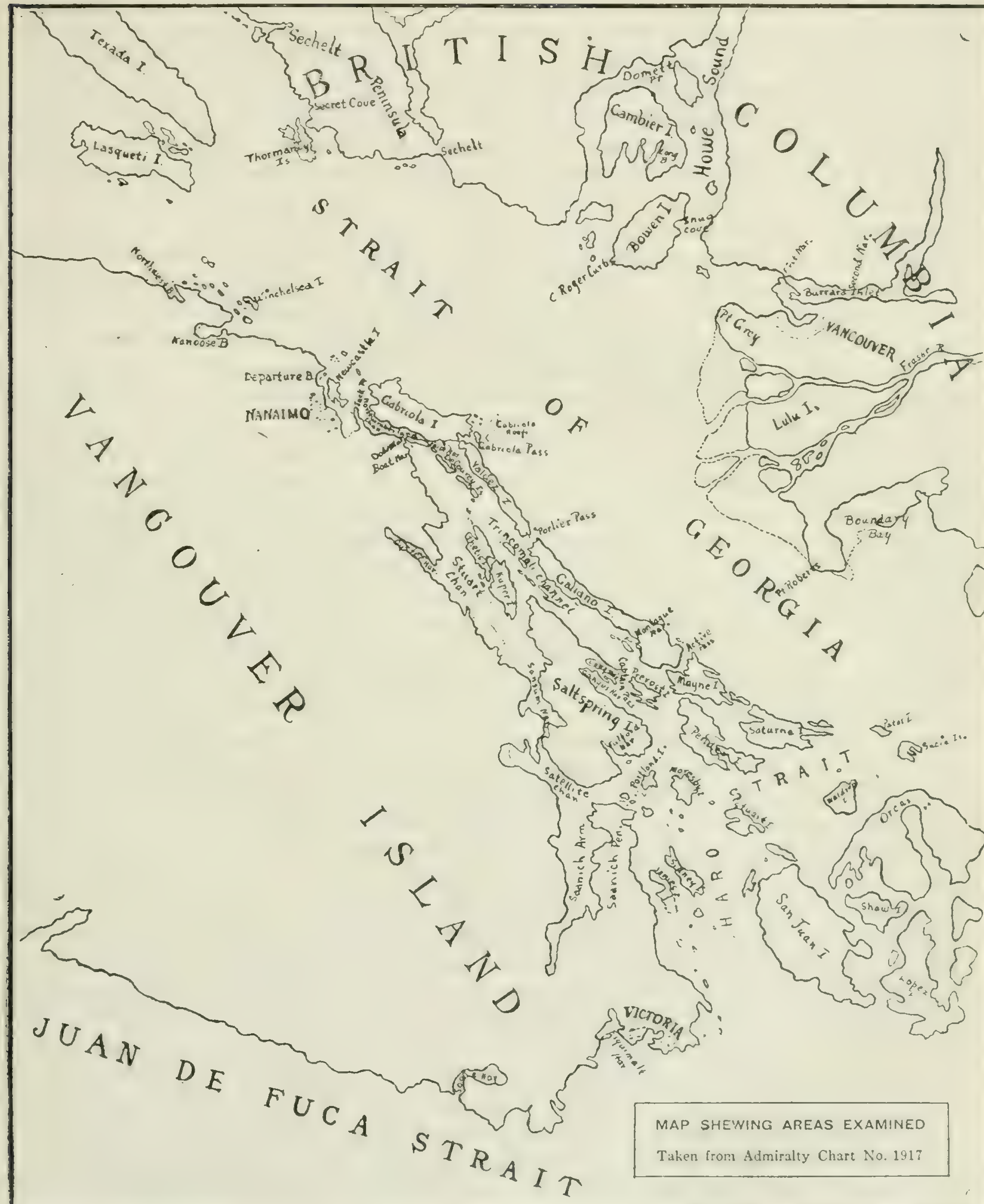
Would the introduction of lobsters on a large scale upset the marine equilibrium so as injure the prospects of any other fishing industry? It scarcely seems possible. The only crustaceans of economic importance found in the district are crabs and shrimps and these are so little fished that they can hardly be said to be of importance at the present time. The marketable crab, *Cancer magister,* prefers to live in shallow water which may be so much lacking in salinity as to be brackish, on a sandy or muddy bottom such as is found at or near the mouth of a river or stream, where there is little or no fucus or kelp, hence his haunts are not likely to be disturbed by the lobster. The shrimps that have hitherto been used for market go more to the other extreme and stay out in the deeper water. These are not much more likely to be disturbed.

10. Areas Examined Described in Detail.

An examination has been made of a considerable area between Vancouver island and the mainland in order to know if the general conditions seem suitable for lobster habitat. This area includes the strait of Georgia and contiguous waters from Texada and Lasqueti islands to the north to Victoria or near it to the south.

The mainland coast in this area, as a whole, does not offer very favourable conditions. Around Thormanby islands, in Buccaneer bay, through Welcome pass and even eastward along the shore behind Trail islands to Sechelt, there is a rather narrow strip that might be available. The logging camps in the neighbourhood seem to have made some change in the nature of the bottom as dredgings made in this vicinity in water of 15 to 30 fathoms brought up more bark than anything else. The area is small and detached from any other area. Secret cove, in Sechelt peninsula, where some of the lobsters were planted in 1905, is at the northern extremity of this area. Eastward from Sechelt to Howe sound the coast is too precipitous and this is true of Howe sound itself. Some lobsters were planted southwest of Gambier island and east of Bowen island but in both these places, although close in shore there is shallow water, it drops off very near by to 100 fathoms or more. Moreover, the sound apparently gets more than the ordinary supply of fresh water if one is to judge from

Lobster Planting, B. C. McLean Fraser.



MAP SHEWING AREAS EXAMINED

Taken from Admiralty Chart No. 1917

readings taken at the surface on August 19, 1914, by Mr. Cameron. At the head of the sound at the mouth of the Squamish river the water was so fresh as to be not even brackish. A little farther out the density was 1·00035. Near Domett point it was 1·004 and even off cape Roger Curtis at the southwest corner of Bowen island it was but 1·006, while at the same time in the open strait and in Departure bay it was 1·018 or more. Burrard inlet supplies a large comparatively shallow area, the length from point Atkinson to Port Moody being about 20 miles but the width is nowhere very great except outside Stanley park or the First narrows. Much of the Fraser river water passes in through the narrows at flood-tide, while at the same time Seymour, Capilano, and other smaller streams add to the supply of fresh water but even then the density is far from being as low as it is in Howe sound. A great trouble would probably arise from the refuse poured into it from Vancouver and other places along the shore. From point Grey southward the shore is in no way suitable as it is all an immense sandbank with the water made brackish by the Fraser river.

The shores of Texada island are precipitous. To the north of Lasqueti island, from Tucker bay to the eastern end of Bull passage, there is a small detached area with some small rocky bays and with plenty of kelp and fucus, that would make a suitable ground for a small number of lobsters. There is no place where there would be a better interchange of water or a better chance of being free from the intermingling of fresh water but here again it is but a short distance into very deep water.

On the Vancouver Island coast the shore to the northwest of Northwest bay is a sandy or gravelly beach extending out into deep water but to the southeast of this bay there is a continuous stretch of good coast reaching to Victoria. The distance from Northwest bay to Victoria is approximately 90 miles, the greatest width of the area with less than 100 fathoms of water is about 25 miles with the average width about half that. The total area must be about 1,000 square miles. Probably half the area is taken up with islands, hence the water area would be about 500 square miles. Over at least one-half of the area the water is less than 30 fathoms deep, and over three-fourths of the remainder the water is not over 50 fathoms.

From Northwest bay to Nanoose bay, 8 miles, conditions seem very satisfactory. The strip here is from 1½ to 2½ miles wide and is dotted with small islands and reefs fringed with kelp. Strong currents pass through the channels to keep a large supply of food material on the move. The bottom is generally rocky, but there are some sandy spots with a good variety of molluscs. The entrance to Nanoose bay (the bay extends in about 4 miles with an average width of about a mile) is rocky and supplied with kelp to the north and the centre but the south shore slopes gradually up to form a sandy beach. Inside the entrance rocks, much of the bottom is covered with mud brought down by the streams that flow into the head of the bay and in general is not very suitable for lobster habitat. From Nanoose bay to Hammond bay there is but a narrow strip of shallow water, nowhere more than a mile wide, with no islands or reefs and very little irregularity in the shoreline. It is well supplied with kelp and other algæ but is much exposed to all storms.

From Neck point at the western side of Hammond bay to Horswell rock at the entrance to Departure bay, a distance of 2 miles, there is a triangular area with the apex at Five Finger island, about 1½ miles from shore, in which conditions are much similar to those in the area west of Nanoose bay, that portion about West rocks and Five Fingers island being especially suitable. It is well out in the open strait, with plenty of current, rocky bottom, kelp and an abundant supply of food material. The plankton taken around these islands is very rich in crustacea. In Departure bay itself the conditions are fair. The northern side of the bay is rocky with clam beds at intervals along the shore; the deeper part of the bay and the south side has rather too muddy a bottom and this is true through the channel separating Newcastle and Protection islands from Vancouver island, forming Nanaimo harbour at the

south end. The water from the Nanaimo river passes through this channel to some extent so that the region is not so suitable as the shallow water strip to the east of the islands which extends well outward towards the middle of the channel. The crude oil that gets into the water as well as the refuse from the Canadian Explosives Works, and the gasolene and oil from the numerous power boats cannot be good for these or other marine forms.

Only a narrow strip connects the Newcastle and Protection area, along the Vancouver island side of Northumberland channel, with Dodds narrows and False narrows where entrance is obtained to the large area of shallow water farther south. Between this strip and Gabriola island there is a wide channel of deeper water ,which is the northern part is 100 fathoms deep in places but farther south seldom more than 60 or 70. Along the Gabriola bluff this deep water comes in close to shore, but to the north of this and on to the north end of the island there are several small bays, with points ending in reefs running out between. This is true at the north end of the island as well, particularly so from the northwest where the shallow water runs out past Snake island, a distance of over a mile and a half, and the northeast, where it runs out past Entrance island, about the same distance.

Beginning with the north end of Gabriola island and extending in a southeasterly direction, past Valdez, Galiano, Mayne, and Saturna islands, there is a very regular coast, with scarcely any small islands except at the entrance of the passes and scarcely a small bay or inlet of any kind. The 30-fathom line is seldom more than half a mile from shore, but the 100-fathom line is from 2 to 3 miles out. With the exception of the portions near the passes, therefore, this coast is not well suited for growing and fishing for lobsters. The passes are shallow and hence are connected with the inside areas, but they may as well be considered here.

At the eastern entrance to Gabriola pass, Breakwater island with the numerous small islands of the Flattop group and the portions of the shores of Gabriola and Valdez islands adjacent, include numerous little bays and channels, points and reefs, and to help matters Gabriola reef extending north and south for a distance of about 2½ miles outside of these islands, shelters an area that is nowhere more than 30 fathoms. Similar conditions exist through the pass itself. On both sides there are numerous small bays separated by rocky points which extend far into the passage as reefs. At Porlier pass (Cowichan gap) the islands on the strait side are represented by reefs only. The characteristics of the pass itself are similar to those of Gabriola pass, with the adjacent shores of Valdez and Galiano islands even more ragged than those of Valdez and Gabriola at Gabriola pass. Active pass agrees very well with Porlier pass in the nature of the eastern entrance, but the shores are more regular than either of the others and the channel is deeper. The eastern entrances of all these passes are rather strongly affected by the Fraser river current especially when this river is in flood. Between Mayne and Saturna islands there can scarcely be said to be a regular passage as the islands and reefs so block up the intervening space, from the Belle Chain of reefs half a mile off shore, almost all the way through to the southwest sides of the islands. There are so many tide-rips and overfalls in this area that, however suitable a place it might be for lobsters it might not be very suitable for fishing. This is somewhat true as well in the neighbourhood of Tumbo island, north of the eastern extremity of Saturna island, although since there are not so many reefs it is not such a dangerous coast. Rounding Saturna island, Haro strait, running at first south of west and then south to the south end of Vancouver island, provides a distinct obstacle to lobster communication with the San Juan islands, as everywhere in mid-channel it is 100 fathoms deep or very little short of it.

South and west of this chain of islands, lying between them and the coast of Vancouver island and extending from Dodds narrows and False narrows all the way to Victoria is a large area, very little of which is apparently unsuitable for lobster

habitat. There is very little water with a depth of over 30 or 35 fathoms, the only part of any size to be excepted being Stuart channel from the south end of Thetis island, Sansum narrows and the northern portion of Satellite channel or, generally speaking, the channel between Saltspring island and Vancouver island. Even in this channel there is seldom 100 fathoms or very near it. In this area the effect of the mixture of fresh water from the Fraser river is much less marked than it is outside of this chain of islands. Judging from plankton observations, low-tide collections and bottom dredgings, there is an abundant supply of food material throughout the area.

Certain inshore locations offer snug retreats and convenient abiding-places such as the lobster has a fancy for. Around the DeCourcy islands there are many such locations. Near Mudge island, with Dodds narrows on one side and False narrows on the other, these are more especially marked. It was in a small bay on the False narrows side of Mudge island that the lobsters thrived for a couple of months in 1905. The adjacent shores of Vancouver island on one side and Gabriola island on the other are of much the same nature. From Pylades island, the last large island of the DeCourcy group, or the smaller Tree island, it is a short distance by way of the Danger reefs to the reefs to the north of Thetis island, and from this along the west side of Trincomali channel, taking in the shores of Reid, Hall, Norway, Wallace, and Secretary islands, Governor rock and Atkins reef, it is good all the way to the entrance of Captain passage. On the other side of the channel the outline of Valdez and Galiano islands is very regular and but little indented until Montague harbour is reached. The Vancouver island coast is much more indented and irregular as far as Oyster harbour, as is the north shore of the harbour, but the south side and from this along the coast southward as far as Crofton, the water along the shore is shallow and the shore itself is sandy or muddy with but few rocks along the whole distance. The west coast of Thetis and Kuper islands is quite regular also, with the exception of a small portion around Telegraph harbour, where there are a number of small islands and reefs. The west coast of Saltspring island and the adjacent coast of Vancouver island are quite regular but there are some very suitable small bays. The rapid progression into deep water in almost every case spoils the desirability of the location.

In the neighbourhood of Captain passage, the conditions are very favourable. In fact the whole coast of Prevost island is very suitable, with its numerous rocky and sandy bays passing inland in a southeasterly and northwesterly direction. On the opposite side of Captain passage the strip between Ganges harbour and Trincomali channel offers similar conditions. Long harbour runs inland for 2½ miles as a narrow inlet. From Ganges harbour southward the shore of Saltspring island is regular with no large indentations and few small ones. This is largely true of the south end of the island as well, with the exception of the entrance to Fulford harbour, where there are numerous small rocky indentations. The whole area between Mayne and Saturna islands on the one side and Pender island on the other is shallow, much of it less than 15 fathoms. The shores are not so very ragged but there are several small bays that would serve for lurking places. The south and west shores of Pender island are quite regular and rather abrupt.

To the east of the north end of Saanish peninsula is a triangular area, approximately 4 miles each way, that offers very favourable conditions. Moresby island forms the eastern apex, with Portland and Piers to the north and the southern point running down to Sidney and James islands. The surface water in this area has a greater density than that at any other part of the region under consideration; it has the largest beds of kelp and, in all probability, all the other conditions that go with these. It cannot be said that the area is limited thus to the south as in reality a continuation of it, a strip from 2 to 4 miles wide extends along the Vancouver island

coast to Victoria. In this strip the large islands are almost absent but there is a fair share of rocks and reefs.

11. Two Methods Suggested in Future Planting Schemes.

To all appearances there are these areas and probably other areas equally as good at other points along the British Columbia coast, which provide all the conditions necessary for the welfare of this crustacean that has become so valuable on account of its increasing scarcity in the last few years. Nothing but experiment with the animal itself can tell us any further whether it will thrive or not and it has been already demonstrated that experiment without continued observation and control counts for little more than no experiment. It could easily be possible to go on putting in a small shipment of lobsters every few years, for this and several succeeding generations, without being any wiser as to whether any survived or not. It certainly would be preferable if another experiment is undertaken to put it on such a basis, no matter what time it takes to do it, that the question should be definitely decided one way or the other. To do this two methods suggest themselves. One of these is to place a large number of lobsters in an area that seems suitable and at the same time is fairly well cut off by land or deep water from adjacent areas. In this way the lobsters would have a chance to move about under conditions as natural as possible and if the numbers were large enough the movements of the plantation as a whole could be followed. I cannot see where anything is to be gained by putting a few here and there over a wide area where it is entirely impossible to make any observations as to how they live or where they go.

The other method would be to place a number, not necessarily so large, in a small bay where the conditions seem satisfactory and impound them there by making the enclosure complete as far as the lobsters are concerned, but not so complete as to hinder a constant interchange of the water supply. This was done in some of the previous experiments, but a net, satisfactory as it may be at the moment, must soon rot and become useless when left constantly in the salt water. A permanent barrier is necessary, either in the form of a weir, of a wooden barrier built after the style of the side of a lobster car, or of a stone or cement wall, with grated openings for the free passage of water. In any case it should be strong enough to stand any storms that might reach it, and sufficiently permanent to last at least a couple of years. This would permit of a more extensive series of observations than the other, but there are certain objections to it. The conditions are to some extent artificial, as enemies, if there are any, would be kept outside of the enclosure, and the food material, to some extent at least, would also. It might be necessary on that account to give an additional food supply. Furthermore, such an enclosed area would of necessity be rather shallow, and if it is necessary for the lobster to get into deep water for a portion of the year, its well-being might suffer if it were kept in the shallow water throughout the year. If, on the Atlantic coast, this movement into deep water is merely to get away from the cold water near shore, that point would not need to be considered seriously, since as has been previously stated, the water would be at a suitable temperature during the winter months as well as during the summer.

12. Expert Supervision Essential.

No matter which method is used, it seems to me that it is absolutely essential to have a suitable man to look after them continuously for two years at least, in order to know if those brought out as seed lobsters would spawn again in British Columbia waters (that is, if Herrick is correct in his contention that lobsters spawn but once in two years). It would be much better to carry this on for six, seven or eight years to find out if the lobsters hatched out in these waters would develop into mature lobsters and propagate.

13. Desirable Condition for Experiment Specified.

If an open area should be decided upon, the following locations seem to be the most suitable: The area between Northwest bay and the entrance to Nanoose bay; around Five Finger island and West rocks; around Mudge island, on either the Dodds narrows or the False narrows side; around Secretary and Wallace islands; around Prevost island and the area east of the north end of Saanich peninsula. To this might be added the area around Breakwater and the Flattop islands, were it not that this location is liable to be much affected by the water of the Fraser river. All these locations are mentioned in the general description.

If the enclosure method is to be used, deciding on a suitable location is a difficult matter. So many of the small bays among the islands are used for anchorage or wharfage and consequently could not well be closed up. To give just one example, there is a fine small bay in the Winchelsea islands, but this is practically the only protected anchorage for small boats between Nanoose and Northwest bays, and since much fishing is done off these islands (locally known as the Grey rocks) it would be a great hardship to the fishermen if that were closed up.

To be suitable for the purpose, the bay must be large enough to allow for the wandering of a large number of lobsters, narrow enough at the entrance so that it can be readily blocked, sufficiently protected that it may not suffer too much from storms, deep enough so that at low-tide there is an abundance of water, varied enough in shoreline to provide rocky clefts and fissures in which the lobster may lurk, and sandy beds where it may dig for shellfish but not muddy enough to spoil it all, well provided with kelp, fucus and other algæ, near enough to strong currents to allow for the bringing in of food material, for the lobsters themselves and for the forms on which they feed, and as free as possible from contamination from fresh water. At the same time it would be well to have it near a suitable location for a permanent habitat so that if the experiment should prove successful it would not be necessary to transport them when it was desirable to liberate them. To get a location with all these conditions is rather a large order. Practically all the shores of all the islands in the district under consideration have been examined, with the results that very few cases were found with any approach to fulfilling them all. There are very many small bays like that in which some of them were impounded in False narrows, that would do very well for a location for a limited period if there were not too many lobsters, but they would not be satisfactory if it was desired to impound a large number for a long period, as it would allow for so little chance for the individuals to move around on account of the overcrowding, more especially at low tide.

14. Six Areas Described as Preferable for Experiment

The location which to me seems the most suitable for this purpose is an inlet, Glenthorne creek, extending into Prevost island from the west. The inlet itself is about a mile long, nowhere more than 250 yards wide, and in some places very much less than that. Its north shore is a narrow neck of land separating it from a similar inlet, Annette creek. Its south shore is not continuous but is made up of two larger islands, several smaller islands or reefs and a point of Prevost island, Glenthorne point. From the extremity of this point to the head of the inlet is about a quarter of a mile, and this portion could readily be inclosed by placing a barrier across from this point to the north side, which here is not more than 100 yards away at low-tide. The portion thus shut in would have a rocky shore line throughout the greater portion at high-tide and throughout about half of it at low-tide, the other part being heavy sand or sandy mud. About one-half of the area has 1½ to 2 fathoms of water at low-tide and but a small portion of the beach goes dry. Through Captain passage, at the entrance of the inlet, a strong current flows a great part of the time and some

of this current comes through the inlet and in and out among the gaps between the islands and reefs, so that a constant interchange of water would be assured. There is practically no drainage area from which fresh water could come, as Ellen bay coming in from the southeast and Annette creek, just north of Glenthorne creek, very nearly cut the island in two, leaving but a very narrow strip between them and the southwest shore of the island. On account of these two inlets being thus situated, no inconvenience is ever liable to arise through the shutting up of the end of Glenthorne creek.

Annette creek is somewhat similarly placed but does not seem nearly so suitable as Glenthorne creek. It reaches in farther as the points on each side reach out farther, but as both shores are complete if a portion of it was closed off the tide current would not be running past the barrier, and hence all the interchange there would be could only be of the nature of a back wash. This probably accounts for the fact that it is much more muddy than Glenthorne creek. The depth of the two is much the same but Annette creek has more shallow water around the shore and in consequence a greater portion would go dry at very low tide.

Just across Captain passage from the mouth of these two inlets, Long harbour extends in a similar way for a distance of 2½ miles into Saltspring island. About half a mile from the entrance some small islands and reefs run parallel to the northeast shore, about 100 yards from it at both ends but more than that at the centre, where there is a small indentation in the shore occupied by a sandy beach. There is a greater variation in depth here, and if it could be blocked at each end in such a way that the tide would pass right through, it might be a suitable location. It would not be so large as the head of Glenthorne creek but in other respects the conditions are somewhat similar.

At the southeastern extremity of DeCourcy island a peninsula extends northward in such a way as to leave a bay between it and the main portion of the island. The entrance to this bay is somewhat cut off by a couple of small islands, and at low-tide a ridge extends and very nearly connects these with the extremity of the peninsula. The area thus inclosed is 500 or 600 yards long and nearly half that width at the widest part but narrowing very much towards the head. The water over the greater portion is 1½ to 2 fathoms deep at low-tide. All of the shore with the exception of the extreme head, where there is a beach, is rocky, the rocks being rough and broken on the one side but smoother and sloping more gradually on the other. A good tide current flows in and out over the reef and between the islands. It is fairly well protected from storms and could readily be inclosed by a barrier across the entrance. No fresh water runs into it and it is not used as an anchorage.

Just south of Boat harbour on the main coast of Vancouver island is a peninsula somewhat similar to that on DeCourcy island. It is not so large but a series of reefs extend from its extremity, protecting the bay almost as well as if the point did project. The opening here is to the southwest instead of to the north. The bay is almost as long but much narrower. Several other bays somewhat similar to this occur between Boat harbour and Oyster harbour, but fresh water runs into the majority of them, and the ranchers use them for anchorage.

A little over a mile from Jack point, not far from Nanaimo, and just before Duke point is reached, there is the entrance to a lagoon over three-quarters of a mile long and from 150 to 200 yards wide, which may be entered readily by small boats at high-tide but is inaccessible at low-tide. The entrance is somewhat narrow and the rocks across the entrance serve as a barrier up to about half tide, with the exception of two narrow passages. This barrier retains the water as the tide goes out so that the water in the lagoon may be at a much higher level than that outside. Even if the water lowers to the levels of the rocks at the entrance only a small portion of the whole area becomes dry. The greater part of it is from ½ to 2 fathoms at the lowest tide. The southern end of it has a bottom of sandy mud, with bunches of eel-

grass, and dries for a short distance out, but near the entrance it is rocky and somewhat deeper with plenty of algæ present. Such animals as sea-urchins, which are usually found in the strong current or where there is a good interchange of water, are here in plenty. Plankton taken at half-tide on August 14 showed an abundance of copepods, cladocera, nauplii, larval ascidians, mollusc eggs, and smaller numbers of several other groups. This lagoon is separated from the Nanaimo river by but a constricted neck of land, through which a narrow passage is cut for row-boats. To see if the Nanaimo river would have any material effect on the water of the lagoon, some samples were taken on October 19, when the river was high from heavy rains. These were taken just at the end of ebb-tide, so that the water from the strait would have the least effect in backing up the water of the river. In Northumberland channel, outside of the lagoon, the surface density was 1·0216, in the lagoon it was 1·0207, while on the Nanaimo river side of the neck of land at the entrance to the boat passage the density was only 1·0014. As the passage is narrow and out of the line of the Nanaimo river current, it would seem that little fresh water passes through.

None of these locations are entirely ideal, but they seem to be the best available. Some of the locations in the area east of Saanich peninsula seem as good as these, but without exception all of them are occupied, at least in the summer when the campers get out along the shore to take advantage of all the suitable protected spots.

15. Summary.

Three attempts to introduce lobsters into British Columbia waters have been made by the Canadian Department of Fisheries, and numerous similar attempts have been made in the Pacific waters farther south by the United States Bureau of Fisheries. It is not known if any of these attempts have been successful, since there has been no system of control or continued observation in connection with the experiments. Further attempts of a similar nature are not liable to give any better results. It would seem to be worth while to know definitely if transplanted lobsters will thrive as the price of lobsters has very materially increased in recent years on account of the decrease of the supply. On the east coast of Vancouver island, and in all probability in many other places, there is a large area that apparently is very suitable for lobster habitat.

If another attempt at transplanting is made, such control of the experiment should be exercised as to decide definitely, one way or the other, as to its success. Two ways to make it possible are suggested. The one is to transplant a large number of lobsters into a large, although somewhat isolated area, where they would have conditions as nearly natural as possible, and hence in no way inclosed. The other is to transplant a smaller number into some inlet, with a barrier across the entrance of sufficient strength to last for years, and yet provided with means of constant interchange with the water out in the open. In either case, the lobsters should be under daily observation for at least two years, to see if seed lobsters would spawn again, or better still for six or eight years to see if young lobsters hatched in the first year would mature and propagate.

XIII.

VARIATIONS IN DENSITY AND TEMPERATURE IN THE COASTAL WATERS OF BRITISH COLUMBIA—PRELIMINARY NOTES.

By C. McLean Fraser, M.A., Ph.D., and A. T. Cameron, M.A., B.Sc.

(With Two Charts and a Map.)

It is well known that two of the chief factors determining the distribution of marine fauna and flora are the salinity and the temperature of the containing water. The series of observations embraced in this paper have been carried out in order to obtain an idea as to the extent to which these factors participate in British Columbia waters, and to see therefore whether a subsequent more exact series of measurements is desirable.

We are not acquainted with any extended series of observations of density and temperature of these waters previously published; while scattered data almost certainly exist bearing on the problem, we have had no opportunity of consulting them. Any previous observations by other observers have not, therefore, been taken into consideration.

Continuous observations have been made at the Biological Station, Departure bay, for a period of four months. Examination of the Pacific coast kelp beds by one of us afforded an opportunity of similar measurements at points over a large part of the British Columbia coast. These, taken together, give data for the variation at a single point (the Biological Station) and for a large number of scattered points. Since the results indicate a considerable variation at the one point, a similar undetermined variation probably exists for many, if not all of the other points, at which only one or very few readings could be made. Only certain general conclusions can therefore be drawn from the second series of readings.

The readings taken at the Biological Station are given in Appendix A, and figured in fig. 1. Those dealing with density will be considered first. They indicate variations in density between the limits 1·013 and 1·022, with a mean value 1·0185. The curve is marked by repeated sudden fluctuations in the sense of a fall with subsequent slower rise. These fluctuations indicate sudden influxes of fresh water. The possibility of tide-effects was tested in the earlier readings by taking numerous readings at high and low tide. The corresponding points lie on the curve and show no marked tidal influence.

The position of the Biological Station is shown in the accompanying coast map. Possible sources of fresh water are: (1) local, small streams flowing into the bay, and the Nanaimo river flowing into adjacent waters 4 miles south (the amount from these sources is practically negligible at the height of summer); (2) large bodies of fresh water poured into the strait of Georgia, by the Fraser river, and through Howe sound and inlets farther to the north. The nearest of these more distant sources is the Fraser river, 30 miles directly across the strait of Georgia. Since the amount of water from this source far exceeds that from those in the near vicinity, this alone need be considered under the second head. We are convinced that the fresh water of the Fraser river, and not that from more local sources, is the cause of the fluctuations here chronicled, on the following grounds:—

(1) The readings throughout Departure bay on June 29 were practically constant. On June 30 a lower reading was obtained outside than that obtained inside

the bay. Hence the local streams flowing directly into the bay could not have caused the largest lowering of density observed during the whole summer.

(2) On July 10 a much lower reading was obtained outside Gabriola pass, in the open strait, than that obtained inside. The tide was then flowing east through the pass. This change could therefore only be produced from some source on the opposite side of the strait, i.e., the Fraser river.

(3) The greatest fluctuation was observed about the end of June, when the water was highest in the Fraser river. Preceding fluctuations were smaller, succeeding fluctuations gradually diminished, corresponding to the gradually diminishing volume of water poured out by the Fraser river.

Fresh water, being less dense, tends to remain at the surface in calm weather, and we consider that the variations in density which we have observed at the Station are caused by large bodies of relatively fresh water travelling directly across the strait from the Fraser river (this does not necessarily mean a noticeably rapid movement). Actual observations off the Sand Heads lightship in calm weather show that with flood tide the Fraser river water is taken in a strong current to the northward, but when the ebb starts it is carried more towards Gabriola pass, Cowichan gap and southward, hence under favourable conditions it is readily conceivable that occasionally bodies of surface water may reach Departure bay comparatively unchanged. With high winds and heavy seas the mixture of fresh water with the deeper salt water naturally takes place more readily and rapidly, while strong currents travelling north or south in the strait would also prevent the fresher water from reaching Departure bay. Since even during the summer months one or more of these disturbing factors is usually in evidence the readings are as a whole nearer the maximum observed than the minimum.

Our conclusions with regard to Departure bay are strengthened by the short series of readings made in Howe sound and in Vancouver harbour (August 19). The former were attributable to the fresh water poured into Howe sound by the Squamish river, since had the Fraser river been responsible similar small figures should have been obtained for Vancouver harbour. With these results may be compared those for Alberni canal and Barkley sound, which are quite similar and similarly explained, since large bodies of fresh water flow into the canal at the head, at Uchucklesit, and elsewhere, and, while higher values were obtained for the middle of the sound, they were still lower than those for normal ocean salinity.

These results indicate that from every large inlet along the coast a similar result may be expected.

Readings taken later than those here recorded show that with the autumn rains and the consequent large increase in flow of the local streams, the effect of these on the surface water becomes strongly predominant. To quote a single instance:

A narrow neck of land terminating in Jack point, separates the flat at the mouth of the Nanaimo river from Northumberland channel. A row-boat passage is cut through this neck about a mile from the point. On the east side, this passage opens into what is called a lagoon although a large portion of it never dries, and this lagoon is directly connected even at low-tide with Northumberland channel by two passages, one of which is quite near the east entrance of the boat passage. On October 19, after heavy rains, a current from the Nanaimo river passed out into the strait in such a way that there was a distinct margin visible, running northeasterly from Jack point, separating it from the surface waters of Northumberland channel. A sample taken just within the current and about a quarter of a mile from Jack point gave a density reading of 1·0129, while a sample taken but a few yards away, outside of the margin of the current, had a density of 1·0216, and on the other hand a sample taken off MacKay point, Newcastle island, about 2½ miles away but in line with the current, had a density of 1·0164. The water in the lagoon

showed a density of 1·0207, almost as high as that in Northumberland channel (1·0216), but the water on the Nanaimo river side of the boat passage was only 1·0014. The temperature was not materially different in the different cases. It was just about low slack water at the time the readings were taken and there was about a foot of water in the boat passage.

It will require much investigation to find out at all definitely the relative value of the influence exerted by the local streams and of the Fraser river in various localities at different times of the year. While we are of the opinion that during the summer months the larger portion of the variation in surface density is due to the Fraser river water, even in Departure bay, we have not sufficient data at present to offer any opinion concerning conditions during the remainder of the year.

From the figures in Appendix B it would appear that the coastal waters between Vancouver island and the mainland can be divided roughly into three large areas: (i) north of Seymour narrows and the Yucultas; (ii) between these and the chain of islands extending southeast from Gabriola island and forming the southern limit to the strait of Georgia; (iii) southwest and south of this boundary. It will be seen from the map that the second section is a relatively closed area. Of these areas (i) and (iii) have an average density distinctly higher than (ii). In the first area the value increases as the open waters of Queen Charlotte sound are approached. In the third area a similar result is noticeable as Haro strait and the strait of Juan de Fuca are neared. The figures indicate an average for (i) and (iii) of the order 1·021 to 1·022, and for (ii), 1·018 to 1·019. The difference is due to the addition of fresh water at different points already referred to.

The variations of temperature readings can be attributed to: (i) the influence of fresh water (Howe sound); (ii) influence of ocean waters (cf. the lowering of temperature on nearing Queen Charlotte sound, Haro strait, Barkley sound, etc.); (iii) special effects produced in shallow waters (indicated by readings at the station, and true for all similar bays) attributable to the influence of air temperatures and shown by the comparison of air and water temperatures on the curves in fig. 1. In the series of readings taken in Departure bay and shown in fig. 1 generally a rise in density is accompanied by a fall in temperature, indicating very frequently, admixture of surface water with water from a lower depth.

These readings both of density and temperature refer only to surface water. The type of variation with depth is shown in fig. 2. It was possible to take but one set of readings of this nature during the time the other readings tabulated were taken, all of the others being taken later. These readings, quoted in Appendix C, give a chance for comparison of water from the deeper part of the strait with that from the shallower bays and channels. They show plainly that the main portion of the variation in both density and temperature occurs in the five fathoms nearest the surface. Below this there is a very slight gradual increase with the depth until 50 fathoms, after which there appears to be little or no variation down to 100 fathoms, the greatest depth at which samples were taken. Below 50 fathoms there seems to be little difference in either density or temperature in different localities in readings taken at or near the same time. The set of readings taken in Departure bay on October 14, after heavy rains had swelled the local streams, that taken in the open strait, east of Breakwater island, on October 26, and that taken at Sand heads on October 2, show the sudden change from water of low density at the surface to water of greater density 5 fathoms down.

For any one set of readings the curve is not quite regular, due to cross currents, irregularity of bottom, etc., but it is quite possible, if a number of sets could be taken during a period of settled weather, that the average would give a fairly regular curve. Even the curve made from the average of those here recorded gives one which is quite satisfactory. A very much extended series of readings is required for any definite statements in the matter.

The following figures show that for these waters, at any rate, values of density and salinity content can be regarded as parallel. The salinity has been assumed to be proportional to the halide content, and this, estimated as chloride by Mohr's method (with silver nitrate, using chromate as indicator). The samples of water were taken from Departure bay and points within 10 miles of it. In the fifth column, P represents the percentage of sodium chloride, and E the percentage excess of the density observed over that of water.

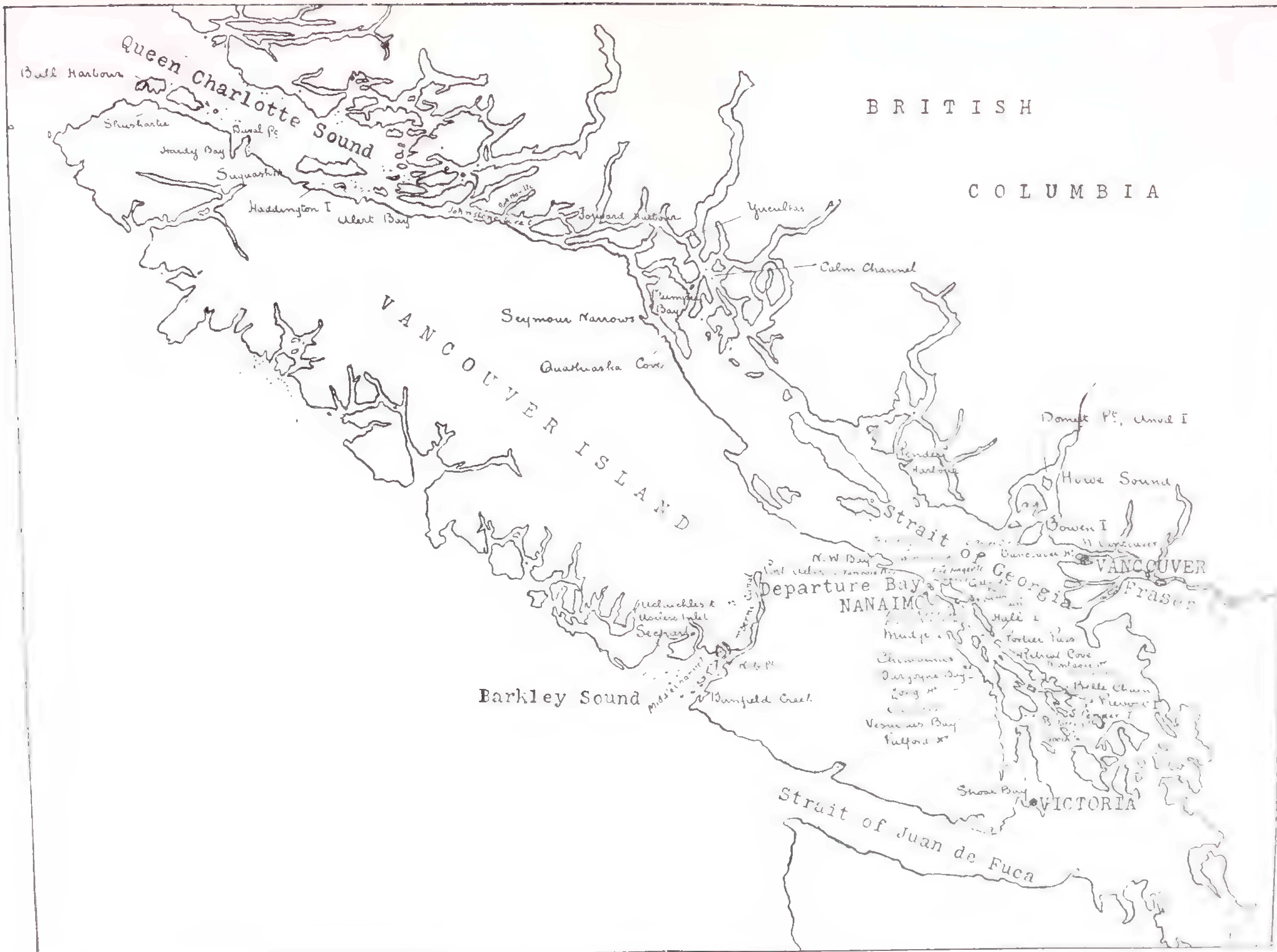
Sample No.	Date.	Density.	Sodium Chloride Content.	P. — E.	Point where taken.
1	12 May 1914............	1·0211	2·584	122	Mudge Island.
2	8 June 1914	1·0209	2·680	128	False Narrows.
3	6 " 1914...........	1·0202	2·460	122	Nanoose Bay.
4	1 " 1914............	1·0178	2·050	115	Departure Bay.
5	12 " 1914............	1·0163	1·994	122	"
6	29 " 1914............	1·0135	1·652	122	"

So far we have been able to work out accurately only one example of the relationship between salinity and distribution, namely, in connection with the Pacific coast kelps. The results, which will be published fully elsewhere, show definitely that for the species *Nereocystis lütkeana* (*bull-kelp*), other factors being constant, with increased salinity is concomitant increased growth, both as to weight and length of individual plants and size of beds, while a second species, *Macrocystis pyrifera* (sea vine) will not grow in such a low mean salinity as is found in area (ii) above defined, i.e., where the salinity falls below a mean value of 1·019 to 1·020, but is always found in waters where the salinity reaches a slightly higher mean value (density 1·021 to 1·022). The surface values of density are fully applicable here, since these kelps grow chiefly at depths of from 4 to 6 fathoms in British Columbia coast waters, while the greater part of each plant remains near the surface continually; hence their conditions of growth are primarily subject to changes in the surface waters.

According to Thompson (British Columbia Fisheries Report, 1914, p. R. 126-R. 130), the abalone, *Haliotis gigantea*, has a similar range to that which we have found to exist for *Macrocystis*. This also is found within the same limits of depth, and probably illustrates a case from the animal kingdom in which the distribution is conditioned by salinity.

We consider that the results so far obtained indicate that further, exact observations should be made over a longer period with a view to determining: (i) to what depth the sudden fluctuations observed in Departure bay and its neighbourhood extend; and (ii) the relative effect of such sudden fluctuations on marine plant and animal life compared with those more regular changes to be observed in the estuary of such a river as the St. Croix (cf. Copeland, Contributions to Canadian Biology, 1906-1910, p. 281).

Such an inquiry would probably be of special importance in relation to proposals to transfer species with sedentary habits such as the lobster and the oyster to a new habitat, and we hope that provision will be made to carry out such observations with a view to solving these and similar questions.


Queen Charlotte Sound
Bull Harbour
Shushartie
Hardy Bay
Suquash
Haddington I
Alert Bay
Forward Harbour
Yuculta
Calm Channel
BRITISH
COLUMBIA
VANCOUVER ISLAND
Seymour Narrows
Quathiaska Cove
Strait of Georgia
Howe Sound
Bowen I
VANCOUVER
Fraser
Departure Bay
NANAIMO
Barkley Sound
Bamfield Creek
Vesuvius Bay
Fulford Hr
Shoal Bay
VICTORIA
Strait of Juan de Fuca

Appendix A.

Readings of Density and Temperature of the Sea-water, and Maximum and Minimum Air Temperatures at the Biological Station, Departure Bay, May to September, 1914.

The sea-water temperatures have been corrected by calibrating the instrument of measurement against standard thermometer (standardized at Kew); the densities were measured by a hydrometer subsequently standardized by calibration in sodium chloride solutions, whose densities were determined with a pyknometer. All the densities have been corrected to 15° C. (and comparison with water at 15° C.). The air temperatures have not been corrected. They were taken by instruments supplied by the Meteorological Office. The results are shown as curves in fig. 1. The water temperatures do not show maximal and minimal readings, so that the comparison with the air readings is not absolute. Initially the water measurements were carried out at times approximating to high and low water as soon as it became evident that tides did not produce an effect, this was discontinued and the readings were made between 8 and 9 a.m. The times given do not of course refer to the air temperatures.

Date.	Time.	Water.		Air Temperature.		Remarks.
		Temperature.	Density.	Maximum.	Minimum.	
1914		° C.		° F.	° F.	
May 12...	8 p. m.	13·9	1·0219	73·2	45·2	High water.
" 13....	2 "	15·5	1·0210	66·7	53·0	Low water.
" 20...	4 "	15·0	1·0216	84·1	46·0	High water.
June 1....	10 a. m.	15·5	1·0178	80·2	55·3	"
"	5 p. m.	14 6	1·0178	....	....	Low water.
" 2....	12 m.	15·9	1·0176	66·5	47·7	High water.
"	5 p. m.	16·1	1·0178	....	....	Low water.
" 3....	2 "	15·7	1-0185	58·8	46·2	High water.
"	7 "	15·2	1·0186	....	....	Low water.
" 4....	3 "	15·1	1·0184	64·2	40·2	High water.
"	9 "	14·5	1.0190	....	....	Low water.
" 5....	....	....	....	63·4	42·6	
" 6....	2 "	14·2	1·0211	68·2	42·0	
" 7....	11 a. m.	14·1	1·0203	56·0	48·4	Low water.
"	6 p. m.	13·9	1·0201	....	....	High water.
" 8....	7 "	14·5	1·0201	60·4	48·0	
" 9....	12 m.	13·7	1·0210	61·0	49·0	
" 10....	1 p. m.	14·1	1·0209	69·0	44·0	
" 11....	1 "	16·0	1·0210	75·0	46·0	
" 12....	2 "	16·3	1·0163	76·0	49·0	
" 13....	8 a. m.	15·6	1·0160	70·0	54·0	
" 14....	9 "	14·5	1·0199	80·2	47·8	
" 15....	11 "	17·9	1·0169	85·2	54·7	High water.
"	7 p. m.	19·5	1·0168	....	....	Low water.
" 16....	1 "	18·5	1·0162	76·3	54·3	
" 17....	2 "	18·8	1·0168	75·2	51·0	
" 18....	9 a. m.	17·1	1·0182	72·2	54·6	Low water.
"	4 p. m.	18·0	1·0168	....	....	High water.
" 19....	9 a.m.	16·6	1·0177	69·2	50·6	Low water.
" 19....	6 p.m.	18·7	1·0178	....	....	High water.
" 20....	10 a.m.	16·6	1·0182	64·0	46·3	
" 21....	10 "	15·9	1·0186	59·0	45·7	
" 22....	9 "	15·9	1·0207	63·3	25·2	Low water.
" 22....	7 p.m.	16·2	1·0210	....	....	High water.
" 23....	12 m.	16·6	1·0206	68·8	43·5	
" 24....	12 m.	15·6	1·0199	59·0	48·8	

APPENDIX A.—*Continued.*

Readings of Density and Temperature of the Sea-water, and Maximum and Minimum Air Temperatures at the Biological Station, Departure Bay, May to September, 1914—Continued.

Date.	Time.	Water.		Air Temperature.		Remarks.
		Temperature.	Density.	Maximum.	Minimum.	
1914		°C.		°F.	°F.	
June 25....	1 p.m.	17·4	1·0168	68·6	49·8	Low water.
" 25....	8 "	17·1	1·0173	....	....	High water.
" 25....	8 "	15·9	1·0202	69·2	50·7	
" 27....	1 "	17·5	1·0201	69·6	51·4	
" 28....	1 "	17·5	1·0194	77·2	47·4	
" 29...	8 a.m.	17·9	1·0131	83·5	54·5	High water.
" 29...	8 p.m.	19·6	1·0135	....	....	Low water.
" 29....	9 "	18·8	1 0131	....	....	High water
" 30....	10 a.m.	18·4	1·0131	85·7	57·0	"
July 1....	1 p.m.	19·3	1·0134	....	....	Low water.
" 1....	5 "	19·7	1 0138	82·2	58·4	High water.
" 2....	8 a.m.	18·4	1·0138	....	....	Low water.
" 3....	....	....	1·0149	85·0	60·8	
" 4....	....	....	....	79·2	59·6	
" 5....	7 p.m.	19·5	....	72·2	54·7	
" 6....	10 a.m.	18·4	1·0171	69·2	55·0	
" 7....	....	....	1·0182	76·8	47·8	
" 8....	....	....	....	77·2	49·4	
" 9....	....	....	....	70·6	54·4	
" 10....	8 p.m.	19·7	....	78·0	54·6	
" 11....	6 "	20·9	1·0179	77.1	55·7	
" 12....	3 "	20·5	1·0152	83·7	61·3	
" 13....	5 "	21·1	1·0151	81·3	61·3	
" 14.	5 "	19·6	1·0155	74·2	56·7	
" 15....	9 a.m.	15·9	1·0159	66·2	57·6	
" 16...	10 "	17·8	1·0202	76·8	56·4	
" 17....	9 "	19·2	1·0181	83·0	55·5	
" 18....	9 "	19·3	1·0173	86·2	61·8	
" 19....	8 "	19 4	1·0174	80·2	60·4	
" 20....	9 "	18·6	1.0189	71·4	51·4	
" 21....	9 "	17·8	1·0191	62·2	49·4	
" 22....	1 p.m.	19·4	1·0193	76.0	50·0	
" 23....	6 a.m.	17·3	1·0198	76·1	54·8	
" 24....	9 "	21·0	1 0210	67·8	51·5	
" 25....	9 "	17·5	1·0208	68·5	54·7	
" 26....	8 "	15·4	1·0204	65·6	53·6	
" 27....	8 "	15·8	1·0211	72·0	45·5	
" 28....	8 "	16·2	1·0193	76·1	49·3	
" 29....	8 "	16·8	1·0183	77·2	49·3	
" 30. ..	8 "	17·1	1·0179	79·9	63·8	
" 31....	8 "	17·4	1·0178	78·2	63·6	
Aug. 1....	8 "	17·2	1·0184	79·9	50·5	
" 2....	8 "	17·1	1·0191	83·3	55·9	
" 3....	8 "	17·2	1·0192	77·0	53·4	
" 4....	8 "	17·4	1·0198	77·0	52·5	
" 5....	8 "	17·2	1.0176	80·0	49·8	
" 6 ...	6 "	17·3	1·0205	68·2	53·0	
" 7....	9 "	16·2	1·0213	63·2	52·0	
" 8....	9 "	16·1	1·0203	71·5	53·2	
" 9....	9 "	17·5	1·0174	77·3	47·5	
" 10....	9 "	17·4	1·0170	81·2	47·4	
" 11....	8 "	17·3	1·0174	82·0	58·4	
" 12 ...	8 "	17·8	1·0181	83·5	56·7	
" 13....	8 "	17·9	1·0184	85·5	56·0	
" 14....	8 "	17·8	1 0186	79·2	60·2	
" 15....	....	....	....	71·5	56·8	
" 16....	9 a.m.	18·9	1·0190	64·4	54·2	
" 17....	8 "	17·3	1·0196	68·5	50·0	

APPENDIX A.—*Concluded.*

Readings of Density and Temperature of the Sea-water, and Maximum and Minimum Air Temperatures at the Biological Station, Departure Bay, May to September, 1914.—Concluded.

Date.	Time.	Water.		Air Temperature.		Remarks.
		Temperature.	Density,	Maximum.	Minimum.	
1914		°C.		°F.	°F.	
Aug. 18...	6 p.m.	18·0	1·0187	80·3	43 0	
" 19....	....	....	....	84·2	52·4	
" 20....	8 a.m.	17·8	1·0176	76·2	56·0	
" 21....	8 "	17·7	1·0182	67·4	53·2	
" 22....	9 "	16·0	1·0209	74·2	51·0	
" 23....	9 "	16·7	1·0195	79·6	54·8	
" 24...	8 "	17·0	1·0189	79·6	57·3	
" 25....	7 "	17·8	1·0182	77·0	57·6	
" 26....	7 "	17·4	1·0189	75·2	54·2	
" 27....	7 p.m.	18·2	1·0194	72·8	50·6	
" 28....	9 a.m.	17·2	1·0197	70·6	53·4	
" 29....	8 "	16·4	1·0200	70·2	49·7	
" 30....	9 "	16·0	1·0202	70·2	53·0	
" 31....	6 "	15·8	1·0195	73·2	53·5	
Sept. 1....	8 "	15·8	1·0180	73·0	48·5	
" 2....	9 "	16·4	1·0190	64·2	49·4	
" 3....	8 "	16·6	1·0186	57·8	52·8	
" 4...	8 "	16·0	1·0197	67·2	51·0	
" 5....	8 "	15·9	1·0201	66·0	45·3	
" 6....	8 "	15·7	1·0201	62·0	46·2	
" 7....	8 "	15·0	1 0201	58·8	51·5	
" 8....	9 "	16·3	1·0210	55·5	47·8	
" 9....	8 "	13·2	1·0213	58·5	46·7	
" 10....	8 "	13·6	1·0213	62·0	51·5	

The density readings in the above table show a mean value of 1·0185, and extreme values of 1·0131 and 1·0219.

Fig. 1 shows the corresponding curves. Where more than one reading of sea-water temperature was taken in any one day, the morning reading was taken for the curve.

Appendix B.

Readings of Density and Temperature of the Sea-water at Various Points in British Columbia Coast Waters.

The temperature readings were corrected as already described. Most of the density measurements were made with an ordinary urinometer, which was calibrated against the other instruments in use. It did not allow such accurate readings.

Place of Reading.	Date.	Time.	Water Temperature	Water Density.	Remarks.
			° C.		
Prince Rupert	July 27	2 p.m.	13·4	1·013	
"	Aug. 7	8 a.m.	11·9	1·015	
Rose Spit, Graham Island	July 29	11 "	11·8	1·022	S.E. gale increasing.
" "	" 30	7 p.m.	11·8	1·022	" "
" "	" 30	9 a.m.	10·2	1·0235	" "
Tree Nob Islands	" 28	1 p.m.	11·8	1·0235	
Egan Harbour, Beaver Pass	Aug. 5	7 p.m.	11·0	1·0195	Much surface water from heavy rains.
White Rocks, Banks Island	" 6	11 a.m.	11·8	1·021	(East side Hecate St.)
Bull Harbour, Hope Island	July 23	7 p.m.	12·0	1·021	Flood tide. Small streams flow into harbour.
" "	" 24	7 a.m.	11·5	1·022	" "
" "		5 p.m.	11·0	1·022	" "
Shushartie		7 "	10·0	1·023	Streams flow in.
Strait, 2 miles west of Duval Pt.		9 "	10·0	1·0255	
Hardy Bay	July 23	1 "	14·3	1·0215	" "
"	" 25	7 a.m.	12·6	1·022	
Suquash	" 23	9 "	11·5	1·021	Ebb tide.
One mile north of Haddington I.	" 25	12 m.	10·4	1·0215	
Alert Bay	" 21	7 p.m.	10·5	1·0215	
"	" 22	5 "	10·6	1·023	Flood tide.
"	" 25	6 "	10·0	1·023	"
"	" 26	6 a.m.	9·6	1·0215	Ebb tide.
Between Plumper and Pearse Island	" 25	5 p.m.	10·5	1·0265	
Johnstone str. off Port Neville.	" 20	9 a.m.	10·6	1·021	
Forward Harbour	" 18	6 p.m.	13·1	1·020	
"	" 19	8 a.m.	13·0	1·020	
"		6 p.m.	11·1	1·021	N.W. wind all day.
"	July 20	7 a.m.	11·9	1·021	
Plumper Bay, north of Seymour Narrows	" 20	2 p.m.	11·2	1·0195	Ebb tide.
Quathiaski Cove, S. of Seymour Narrows	" 20	5 "	11·0	1·0195	"
Middle of Calm Channel	" 18	1 "	15·7	1·0145	Flood tide.
Pender Harbour	" 17	7 "	20·4	1·0195	
Howe Sound, 2½ miles from head	Aug. 19	12.25 p.m.	12·7	0·998	Flood tide. 100 yds. inside last tide mark.
Howe Sound, 2½ miles from head		12.35 "	14.6	1·0035	100 yds. outside last tide mark.
Howe Sound, 11 miles from head	Aug. 19	1.20 p.m.	15·6	1·004	(East of Donett Pt.)
Howe Sound, 26 miles from head		3.30 p.m.	15·6	1·006	(Off C. Roger Curtis).
North Vancouver, Burrard Inlet	July 23	8 p.m.	14·0	1·0186	H.W. slack.
" "	" 24	7 a.m.	14·6	1·0155	"
" "	" 25	6 a.m.	14·9	1·0148	"
Vancouver Harbour	Aug. 19	5 p.m.	14·7	1·015	High tide.
Ballenas Island	July 29	12 m.	17·1	1·0188	
Northwest Bay	June 6	1 p.m.	17·1	1·0200	
Winchelsea Island	July 29	10 a.m.	17·9	1·0178	
Nanoose Bay	June 6	11 a.m.	14·2	1·0202	
"	July 31	1 p.m.	17·4	1·0179	
Five Finger Island	June 23	11 a.m.	17·6	1·0208	
" "	Aug. 14	9 "	17·6	1·0194	
Snake Island	June 4	8 p.m.	13·9	1·0207	

Appendix B.—*Concluded.*

Readings of Density and Temperature of the Sea-water at Various Points in British Columbia Coast Waters—Concluded.

Place of Reading.	Date	Time.	Water. Temperature	Water Density.	Remarks.
			° C.		
Departure Bay, north side.....	" 29..	8.30a.m.	17·9	1·0131	
" Brandon Island	....	9.00 "	....	1·0138	
" East side	....	9.45 "	18·8	1·0135	
" Further east...	....	10.20 "	....	1·0135	
" Centre...	....	9 55 "	....	1·0138	
" North side....	....	11.30 "	....	1·0133	
" North side.....	June 30..	10.30 "	18·4	1·0131	
" Northeast corner	....	11.00 "	....	1·0135	
" Outside Bay, to Northeast ...	....	10.50 "	....	1·0130	
False Narrows..	June 8..	12 m....	11·0	1·0204	Flood tide.
Dodds Narrows, north side...	" 26.	2 p.m...	14·4	1·0211	"
" South side....	May 12..	11 a.m...	11·7	1·0211	"
Inside Gabriola Pass...... ...	July 10..	1 p.m..	16·5	1·0185	Tide flowing East.
Outside "	....	2 "	19·6	1·011	" "
Southwest of Cowichan Gap...	June 26..	2 "	13·9	1·0207	" "
Hall Island.........	Aug. 17..	2 "	16·1	1·0165	
Retreat Cove, Galiano Is	July 9..	9 "	15·6	1·0195	
" "	" 10..	8 a m...	14·5	1·0205	
Montague Har., "	" 9..	6 p m...	15·4	1·0185	
Miner's Bay, Mayne Is........	" 8..	6 "	11·7	1·022	
" "	" 9..	8 a.m...	12·0	1 0195	
Belle Chain, north of Saturna Island................ ..	" 8..	2 p.m...	14·2	1·020	
Head of Long Harbour, Saltspring Island......	Aug. 18..	12 m....	16·0	1·0185	
Ganges Harbour, Saltspring Is.	July 9..	2 p.m...	16·4	1·0195	
Fulford Harbour, " ..	" 7..	8 "	13·4	1·0225	
" " ..	Aug. 17..	9 "	15·5	1·0195	
" " ..	" 18..	7 a.m...	15·4	1·0175	
Chemainus Bay....	" 27..	11 "	19·2	1·0201	
Vesuvius Bay, Saltspring Is...	" 26..	1 p.m...	19·0	1·0201	
Burgoyne Bay, " ..	" 26..	7 "	17·8	1·0211	
" "	" 27..	7 a.m...	16·8	1·0211	
South of Prevost Island........	July 9..	4 p.m...	....	1·0215	
South Pender Wharf.........	" 7..	7 "	13·8	1·022	
"	" 8..	8 a.m...	....	1·0215	
South of Morseby Island. ..	" 7..	4 p.m...	....	1·0215	
Between Comet and Gooch Is..	" 7..	12 m....	....	1·0225	
Shoal Bay............	" 7..	10 a.m...	15·5	1 020	Inshore.
Port Alberni......	Aug. 25..	1 p.m...	19·7	1·0035	
Off Nob Pt., outside Alberni Canal.........	" 25..	5 "	15·6	1·0175	
Outside Uchucklesit Harbour in Canal................	" 27..	8 a.m...	.. ..	1·0165	
Inside Uchucklesit Harbour...	" 26..	7 p.m...	17·1	1·0165	
Head of Useless Inlet.........	" 26..	6 "	17·1	1·0175	
Neck " "	" 26.	6 "	17·1	1·0285	
Sechart..................	" 26..	2 "	16·3	1·022	
Middle of Middle Channel, Barkley Sd................	" 26..	12 m....	14·3	1·022	
Banfield Creek................	" 25..	7 p.m...	16·0	1·0195	
"	" 26..	9 a.m...	14·9	1·0205	

Appendix C.

Readings of Density and Temperature of the Sea-water at Various Depths.

Place of Reading.	Date.	Time.	Depth.	Temperature.	Density.
			Fath.	° C.	
1. Centre of Departure Bay in 25 fathoms of water.	July 15....	3 to 4 p.m ...	0	17·3	
			1	16·1	
			2	15·8	
			3	15·3	
			4	14·4	
			5	13·5	
			10	12·1	
			15	11·3	
			20	10·8	
			25	10·4	
2. East of Five Finger I. in 120 fathoms of water.	Sept. 9....	3 to 5 p.m	0	13·1	1·0218
			5	10·69	1·0228
			10	10·50	1·0228
			20	9·96	1·0228
			50	8·84	1·0230
			100	8·71	1·0238
3. 200 yards West of Sand Heads Lightship in 30 fathoms.	" 28....	1·30 to 3 p.m....	0	12·70	1·0102
			5	10·96	1·0220
			10	10·32	1·0223
			20	9·70	1·0223
4. 2½ miles East of south end of Breakwater I. in 80 fathoms.	Oct. 2....	11·30 to 12·30...	0	....	1·0229
			5	......	1·0235
			10	....	1·0239
			20	....	1·0251
			50	....	1·0251
5. 1½ miles northeast of Porlier Pass in 90 fathoms.	" 2....	2 to 3 p.m	0	....	1·0226
			5	....	1·0235
			10	....	1·0239
			20	....	1·0245
			50	....	1·0245
6. Centre of Departure Bay in 25 fathoms..	" 14....	9·30 to 11·00....	0	11·6	1·0116
			1	9·85	
			2	9·70	
			3	9·55	
			4	9·45	
			5	9·35	1·0220
			10	9·25	1·0220
			20	9·16	1·0226
7. East of Five Finger I. in 120 fathoms...	" 21....	9·30 to 11·00....	0	10·72	1·0225
			5	9·96	1·0227
			10	9·67	1·0242
			20	9·40	1·0247
			50	9·05	1·0247
			100	9·05	1·0247
8. 3 miles east of south end of Breakwater I. in 120 fathoms.	" 26....	11·45 to 1·00....	0	11·39	1·0151
			5	10·29	1·0217
			10	10·15	1·0223
			20	9·72	1·0239
			50	9·14	1·0249
			100	9·14	1·0251
9. Pylades Channel, ½ mile south of west entrance to Gabriola Pass in 30 fathoms.	" 26....	2·30 to 3·00.....	0	11·00	1·0205
			5	10·11	1·0217
			10	10·00	1·0235
			20	9·72	1·0241

The temperature readings were made, in the first and part of the sixth set, with a Negretti and Zambra deep-sea thermometer, standardized against the other thermometers used, and in the remaining series, with a Richter deep-sea thermometer, standardized at the Physikalische Technische Reichanstalt, Charlottenburg. The samples of water were obtained in a Pettersen-Nansen deep-sea water bottle. As the density readings were taken at room temperature, the correction for 15° C. has been applied in each case.

Some curves to illustrate are shown in fig. 2.

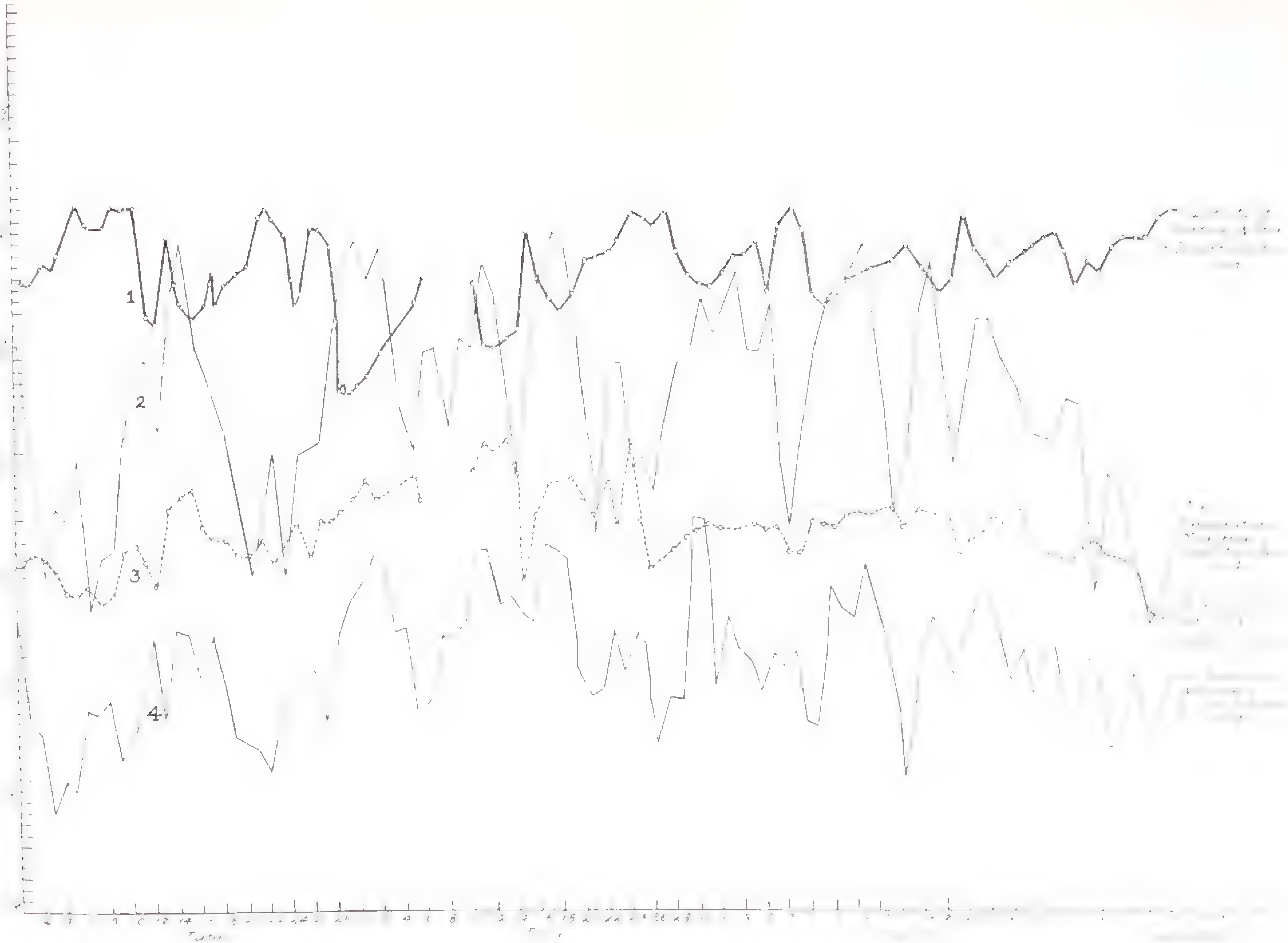


Fig. 1. Four cur[illegible] surface density curve and the others temperature curves. Beginning with the uppermost they are in order: 1. Density of surface water; 2. Air temperature maximum; [illegible] Temperature of surface water; 4. Air temperature minimum. All of them refer to Departure Bay readings from June 1 to September 9, 1914.

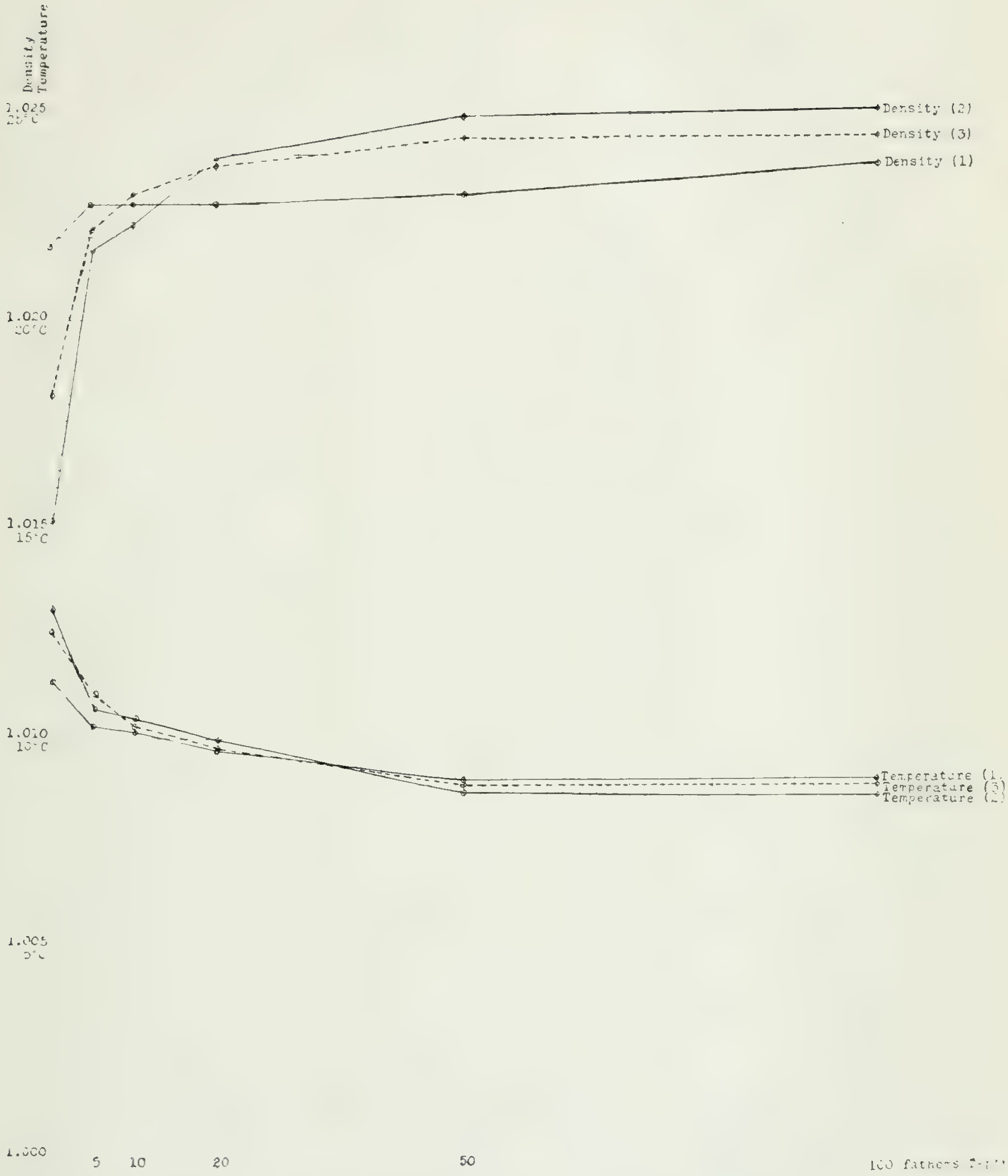


Fig. 2.—Three density curves and three temperature curves, the upper set being the density curves, No. 1 density curve is for the readings obtained near Five Finger Islands on Sept. 9, as an example of a set where the surface water is of high density and hence little difference between the surface water and water at depth. No. 2 is that for the readings taken in the open Strait, east of Breakwater I., on Oct. 26, as an example of an instance when the surface water was of low density and hence differed materially with that at depth. No. 3 is made from the averages for the various depths of all the readings recorded in Appendix C. The temperature curves 1, 2 and 3 correspond to the density readings similarly numbered.

XIV.

AN INVESTIGATION OF THE BAYS OF THE SOUTHERN COAST OF NEW BRUNSWICK WITH A VIEW TO THEIR USE FOR OYSTER CULTURE.

By J. W. Mavor, E. Horne Craigie, and J. D. Detweiler.

(With a Map showing Stations of Observation.)

1. Introduction.

The observations recorded in the present paper were made for the purpose of ascertaining what bays could be found on the southern coast of New Brunswick which supplied the conditions required for oyster culture. The investigation must be regarded as of a preliminary nature. Nearly all the observations were made between August 13 and 17 during two cruises with the motor-boat *Prince* of the Biological Station at St. Andrews. All the bays between the St. Croix river and St. John were visited, observations made on the temperature, salinity, and plankton, and the contents of dredgings determined. The stations at which this was done are listed below and their position marked accurately on the accompanying map. It was originally intended to include the Upper St. Croix river, Pegano cove, Oak bay, and Warwig creek in the list of stations, but lack of time prevented this. In 1910, Mr. G. G. Copeland[1] made hydrographic observations in these bays. His stations have been placed on the map and his data are given in our table of hydrographic observations. Mr. G. G. Copeland also made in the same year observations near our stations in Passamaquoddy bay. These observations also are given in tabular form. His temperatures, which were given in degrees Fahrenheit, have been reduced to the Centrigrade scale. In some cases records are given of dredgings made at the stations in previous years.

For the direction of the investigation and the methods used, Dr. J. W. Mavor is responsible, for the hydrographic observations, Mr. E. Horne Craigie, and for the dredging, Mr. J. D. Detweiler.

A LIST OF THE STATIONS REFERRED TO IN THIS PAPER.

Station 1. St. Croix river. Mr. Copeland's station 3.
" 2. Pagan's cove. Mr. Copeland's station 5B.
" 3. Oak bay. Mr. Copeland's station 5A.
" 4. Mouth of Warwig creek. Mr. Copeland's station 5D.
" 5. Brandy cove, equally distant from sides and end.
" 6. Chamcook harbour, between the bars, off an old weir, the highest hill west of Chamcook hill being between the two buildings of the Canadian Sardine Company's factory.
" 7. Chamcook harbour, on a line between the factory and the opposite point, the lighthouse being in the centre of the height on the outer point.

[1] G. G. Copeland. The Temperatures and Densities and Allied subjects of Passamaquoddy Bay and its environs. Their Bearing on the Oyster Industry. Contributions to Canadian Biology being studies from the Marine Biological Stations of Canada, 1906-10, Ottawa, 1912, pp. 281-294.

Section 8. Bocabec river.
" 9. Bocabec river, farther out.
" 10. Digdeguash bay.
" 11. Magaguadavic river, near the mouth.
" 12. L'Etang harbour, off Indian point.
" 13. L'Etang harbour, off Trainor's landing.
" 14. Black's harbour, off Connors' factory.
" 15. Black's harbour, head of bay, equidistant from end and sides.
" 16. Beaver harbour.
" 17. Lepreau, off point with Square House.
" 18. Head of Musquash bay.
" 19. Bay inside Mahogany island.
" 20. Bay W.S.W. of Shag rocks (near St. John).

Oyster Culture, Southern New Brunswick. Mavor, Craigie and Detweiler.

2. Hydrographic Observations.

For taking the water samples a Pettersson-Nansen water bottle was used. This consists of an insulated metal cylinder, open at both ends, which slides vertically on two parallel brass rods. At the lower end of the brass rods a cap is fastened, which, when the cylinder is lowered, closes its lower end. The upper end of the cylinder is closed by a similar cap, which slides on the brass rods above. The apparatus is so constructed that it can be lowered down with the cylinder open and, when it arrives at the depth desired, can be closed by sending a weight down the sounding wire.

The temperatures were taken with a deep-sea reversing thermometer. In most cases the Richter reversing thermometer attached to the water bottle was used. (Laboratoire Hydrographique Kobenhavn, Preisliste, 1914, No. 75, Thermometer No. 164). In the other cases a reversing thermometer by Negretti and Zambra, No. 170664, was used. In both of these thermometers the mercury column is narrow at a point just above the reservoir. By reversing the instrument at any required depth the mercury column is broken at the narrow part. The scale is marked on the glass so that the temperature at the time of reversing can be read off from the length of the broken off part of the mercury column. In the Richter thermometer an accessory thermometer was included in the same case in order that a correction for the expan-

sion of the mercury column due to the higher temperature of the air in which the reading was taken could be made. The Richter thermometer was reversed by the same messenger which reversed the water bottle. The Negretti and Zambra thermometer was used on a separate sounding line in a Maghnani case, which is reversed by a propeller which turned only when the thermometer was being raised.

The Richter thermometer had been tested by leaving it in the standard temperatures for fifteen minutes. It was found that readings made after the thermometer had remained four minutes at a given depth differed from those obtained after fifteen minutes by less than one-tenth of a degree. It was also found that the correction for the expansion of the mercury column for the temperatures measured was about twenty-five thousandths of a degree. In the work, the thermometer was left at the required depth for four minutes and the correction neglected. Tests with the Negretti & Zambra thermometer showed it to reach the temperature of the surrounding water after three minutes. In the above observations it was left at the depth recorded for three minutes.

The densities were determined with the hydrometer at room temperature and then corrected to read at 60° F. or 15·56° C. by Buchanan's[1] diagram.

Station.	Date.	Tide.	Depth.	Air Temp.	Bottom Temp.	Bottom Density.	Nature of Bottom.
				°C.	°C.		
[1]1	July 14 1910	$\frac{2}{3}$ ebb	3 Fath.	30·1	13·2	1·0085	
	〃 20 〃	Flood	4 〃	21·1	13·0	1·021	
2	〃 6 〃	$\frac{1}{2}$ ebb	4 〃	20·6	9·9	1·023	
	〃 13 〃	$\frac{1}{6}$ flood	2 〃	17·2	12·7	1·0213	
	Aug. 10 〃	$\frac{1}{2}$ flood	3 〃	16·1	10·7	1·022	
	〃 26 〃	$\frac{3}{16}$ ebb	3 〃	21·7	12·8	1·0236	
	〃 31 〃	$\frac{5}{6}$ flood	4 〃	18·3	13·2	1·0231	
3	July 6 〃	$\frac{1}{3}$ ebb	4 〃	17·1	9·7	1·023	
	〃 13 〃	$\frac{1}{6}$ flood	2 〃	17·2	11·8	1·0212	
	Aug. 10 〃	$\frac{1}{2}$ flood	3 〃	16·1	9·4	1·023	
4	July 5 〃	$\frac{2}{3}$ 〃	5 〃	15·6	9·7	1·0225	
	〃 6 〃	$\frac{1}{3}$ ebb	5 〃	18·7	10·5	......	
	〃 14 〃	Ebb	5 〃	26·7	10·8	1·023	
	〃 19 〃	$\frac{1}{3}$ ebb	5 〃	27·5	10·7	1·022	
5	Aug. 21 1914	$\frac{1}{3}$ 〃	5 〃	17·3	11·1	1·02455	
6	〃 13 〃	Ebb.	5 〃	......	12·6	1·02418	Mud.
7	〃 13 〃	〃	6 〃	......	12·4	1·02426	〃
8	July 3 〃	......	1·5 〃	......	10·7	1·02354	
9	Aug. 13 〃	$\frac{1}{3}$ ebb	7 〃	......	10·8	1·02445	Sand
10	〃 13 〃	$\frac{1}{6}$ 〃	4 〃	......	11·0	1·02465	Mud.
11	〃 13 〃	Flood	11·5 〃	......	10·4	1·02498	
12	〃 17 〃	$\frac{1}{6}$ ebb	3·6 〃	20·0	13·1	1·02454	Mud and hard bottom.
13	〃 17 〃	$\frac{1}{6}$ 〃	3 〃	21·1	15·5	1 02414	Mud and shells
14	〃 14 〃	$\frac{5}{6}$ flood	4·5 〃	......	10·9	1·02459	Mud.
15	〃 14 〃	$\frac{1}{2}$ ebb	1·5 〃	......	13·2	1·02452	〃
16	〃 17 〃	Ebb	4 5 〃	17·5	11·2	1·02443	Gravelly mud.
17	〃 17 〃	$\frac{1}{2}$ ebb	3 〃	16·7	12·2	1·02440	Mud.
18	〃 17 〃	$\frac{1}{3}$ 〃	2·5 〃	16·5	12·3	1·02411	〃
19	〃 17 〃	Flood	5 〃	14·8	11·4	1·02412	〃
20	〃 17 〃	Flood	5 〃	14·4	11·3	1·02415	〃

[1] The data given under stations 1 to 4 are quoted from Mr. G. G. Copeland's tables. The readings on the Fahrenheit scale have been converted into the Centigrade scale.

It has not been found possible accurately to locate Mr. Copeland's stations, but where his observations have been taken very near some of the new stations, his tem-

[1] J. Y. Buchanan. "Report on the Specific Gravity of Samples of Ocean water, observed on board H. M. S. *Challenger* during the years 1873-76." Report of the Scientific Results of the exploring voyage of the *Challenger*, Physics and Chemistry, Vol. 1, 1884, Diagram 1.

peratures have been converted to the Centigrade scale, and are here given for comparison:—

Copeland's station.	Near station.	Date.	Tide.	Depth.	Temp.	Density.
					°C.	
26......	9	July 26 1910...	$\frac{1}{3}$ flood...	1 Fath.	11·2	1·022
		Aug. 28 " ...	$\frac{1}{3}$ ebb....	2 "	15·6	1·0241
28......	10	July 26 " ...	$\frac{1}{2}$ flood...	2 "	11·7	1·023
		Aug. 3 " ...	$\frac{1}{6}$ ebb....	3 "	11·2	1·0225
33......	11	" 3 " ...	Flood.....	10 "	10·7	1·0
		" 28 " ...	$\frac{1}{2}$ ebb....	8 "	11·9	1·0245

3. Dredgings.

Dredgings were made at the following stations and the mollusca obtained determined. In some cases records of dredgings made previously without regard to this report are included:—

Station 5—

Date, July 6, 1913. Depth, 3 fathoms. Bottom, sawdust.

Dredgings—*Thracia myopsis* Beck, 1.
Leda tenuisulcata Stimpson, 1.
Tritia trivittata Adams, 1.
Cytherea conversea Verril, 2.

Station 6—

Date, July 11, 1913. Depth, 8 feet. Bottom, sand.

Dredgings—*Yoldia limatula* Say, several.

Station 10—

Date, August 16, 1913. Depth, 5 feet. Bottom, mud.

Dredgings—*Yoldia limitula* Say, 1.
Cardium pinnulatum Conrad, 1.
Chiton albus Montagu, 2.
Yoldia sapotilla Gould, several.
Bela sp., 1.

Station 12—

Date, August 16, 1914. Depth, $3\frac{3}{4}$ fathoms. Bottom, mud and stones.

Dredgings—*Polynices heros* Say (small), 8.
Polynices trisereata Say, 1.
Siphonorbis pygmeus Gould, 4.
Venericardium borealis Conrad, 17.
Aporrhais occidentalis Sowerby (dead), 1.
Cylichnia alba Brown, 2.
Thyasira gouldii Phillippi, 3.
Bella pleurotomasia Adams, 1.

Station 13—

Date, August 17, 1914. Depth, 3 fathoms. Bottom, mud and shells.

Dredgings—*Modiola modiolus* Lamark, 1.
Pecten magellanicus Gmelin (dead), 1.
Tritonofusus stimpsoni Morch, 1.
Saxicava rugosa Gould, a few.
Cardium pinnulatum Conrad, 2.
Doris sp., 4.
Chiton albus Montagu, 1.

Station 16—

Date, August 17, 1914. Depth, 4½ fathoms. Bottom, gravelly mud.

Dredgings—*Astarte undata* Gould, 1.
Tritia trivittala Adams, 1.
Venericardium borealis Conrad, 1.
Polynices heros Say, 4.
Polynices trisereata Say, 6.
Cardium pinnulatum Conrad, 2.
Cylichnia alba Brown, 6,
Utriculus.
Margarita, 3.
Leda tenuisulcata Stimpson, 1.
Cyclus (Cyprina) islandica Lamark, 1.

Station 17—

Date, August 17, 1914. Depth, 3 fathoms. Bottom, mud.

Dredgings—*Polynices heros* Say, 1.
Astarte sp. (small), 1.
Yoldia sapotilla Gould, 3.
Leda tenuisulcata Stimpson, 2.
Polynices triseriata Say, 9.
Cyclus (Cyprina) islandica Lamark, 1.
Lyonsia hyalina Conrad, 2.

XV.

HYDROGRAPHIC INVESTIGATIONS IN THE ST. CROIX RIVER AND PASSAMAQUODDY BAY IN 1914.

By E. Horne Craigie, *University of Toronto.*

(With One Chart and Twenty-three Figures.)

During the month of August, 1914, the writer, under the direction of Dr. J. W. Mavor, and with his constant and active assistance, undertook to make a series of hydrographic observations in Passamaquoddy bay and the St. Croix river. The object of this work was to obtain as much information as possible not only about the actual temperatures and densities of the water, but also about the nature of the currents of warm and cold water, how these are affected by the tides, etc. Such observations, besides being of importance and interest in themselves, are valuable on account of their bearing upon the haunts and habits of fish frequenting the waters studied, or passing through these waters in their migrations.

It is to be regretted that, owing to lack of apparatus, the work could not be started earlier in the season, and that, on account of the other work being carried on at the same time, more data could not be obtained. It is also regrettable that no current-meter of any kind was to be had, as some observations with such an instrument would undoubtedly throw much light upon the subject by indicating the direction and strength, as well as the fluctuations of the currents at various points.

For taking the temperature observations, reversing thermometers were used. These have already been described in the report on the hydrographic work in connection with the "Investigation of the Bays of the Southern Coast of New Brunswick with a View to Their Use for Oyster Culture." The Pettersson-Nansen water-bottle, with which the water samples were obtained at points of considerable depth, is described in the same report. At points near the surface and at the shallower stations, the water samples were taken by means of a small water-bottle manufactured by Negretti and Zambra, London. This consists of a brass cylinder holding a little less than a pint, into the top and bottom of which fit two caps connected by a rod. The top of the rod is held by a hook above the cylinder, the bottle thus being kept open, and in this condition it is lowered to the depth where a sample is to be taken. A messenger is then sent down the line and releases the hook, whereupon the caps are pulled into place by two springs inside the cylinder, thus closing the bottle firmly. In order to be sure that the sample represented the water at the point where the bottle was closed, the bottle was jerked up and down a little and allowed to remain a few moments before the messenger was sent down.

The Richter thermometer,[1] which was attached to the Pettersson-Nansen water-bottle, was always allowed to remain down five minutes, while the Negretti-Zambra thermometer[2] was usually left for three minutes, these times having been found to allow the thermometers to give accurate readings. It was found that the correction for the expansion of the mercury column at the temperatures measured averaged about twenty-five thousandths of a degree, which was neglected in recording the temperatures.

---

1 Laboratoire Hydrographique, Kobenhavn, Preisliste, 1914, No. 75, Thermometer No. 164.
2 Maghnani pattern frame, Negretti and Zambra thermometer No. 170,664.

The density of the water samples was determined by means of a delicate hydrometer at room temperature, and corrected to read at 15·56° C. by Buchanan's diagram,[3] as in the case of the densities recorded in the report referred to above. The nature of the bottom at each station was determined by means of soap in the bottom of the sounding-lead. The data obtained are tabulated at the end of the report.

The stations were selected so as to give four vertical sections, two of the lower St. Croix river, one of Passamaquoddy bay from Tongue Shoal light to Pendleton island, and one of the Western channel, the last section being the deepest studied in this investigation. The numbers and locations of the stations are as follows:—

Station 1. On a straight line across the St. Croix river at the Biological Station, such that the flagstaff on the end of the pier is in line with the centre of the window in the water tower, 0·3 mile from the Biological Station.
" 2. On the same line 0·5 mile from the Biological Station.
" 3. On the same line, 0·7 mile from the Biological Station.
" 4. On the same line 1·1 mile from the Biological Station.
" 5. On a straight line across the mouth of the St. Croix river at St. Andrews, such that the two beacons at the north end of the harbour are in line. In the centre of the steamer channel beside the inner beacon.
" 6. On the same straight line, at the buoy just outside the outer beacon.
" 7. On the same straight line, 1·7 mile from the St. Andrews shore.
" 8. On the same straight line, 2·1 miles from the St. Andrews shore.
" 9. On the same straight line, 2·4 miles from the St. Andrews shore.
" 10. On the same straight line, 2·7 miles from the St. Andrews shore.
" 11. On a straight line drawn from Tongue Shoal light to Deer island, such that Tongue Shoal light always appears in the centre of Chamcook hill. At the buoy off Tongue Shoal light.
" 12. On the same straight line, 0·8 mile from Tongue Shoal light.
" 13. On the same straight line, 1·3 mile from Tongue Shoal light.
" 14. On the same straight line, 1·8 mile from Tongue Shoal light.
" 15. On the same straight line, 2·4 miles from Tongue Shoal light.
" 16. On the same straight line, 2·8 miles from Tongue Shoal light.
" 17. On a straight line drawn across the Western passage from the first island south of Frost ledge to the highest part of Clam Cove head, 0·15 mile from small island.
" 18. On the same straight line, 0·3 mile from small island.
" 19. On the same straight line, 0·6 mile from small island.

The distances recorded in the above table are in geographical miles. The points were determined by landmarks upon the shore and were afterwards located on the chart. The exact position of these stations is shown upon the accompanying map, upon which the beacons and the Tongue Shoal light, which were used in determining the sections, are also indicated. The 10-fathom line has been inserted to show the shape of the deeper part of the basin, with a tongue extending out from St. Andrews. The part of the 10-fathom line extending along the shore of Deer island from the Western passage to Letite passage was not marked on any of the charts examined and has been filled in as accurately as possible from the soundings recorded on the chart. It is possible that a very narrow channel over 10 fathoms deep runs right through Letite passage, which appears at the extreme right of the map. The compass marked on the map shows the direction of the magnetic needle.

[3] J. Y. Buchanan—"Report on the Specific Gravity of Samples of Ocean Water, observed on board H. M. S. Challenger during the years 1873-76." Report of the Scientific Results of the Exploring Voyage of the *Challenger*, Physics and Chemistry, Vol. 1, 1884, Diagram 1

From the data recorded a temperature curve for each set of observations at each station was drawn, and from the graphs thus obtained, isothermal sections were constructed. The isotherms in every case were taken to represent the lowest limit of the temperature marked upon them.

The graphs show that at different stages of the ebb-tide, there is not much change in the shape of the curve, but in the case of the section of the St. Croix river at the

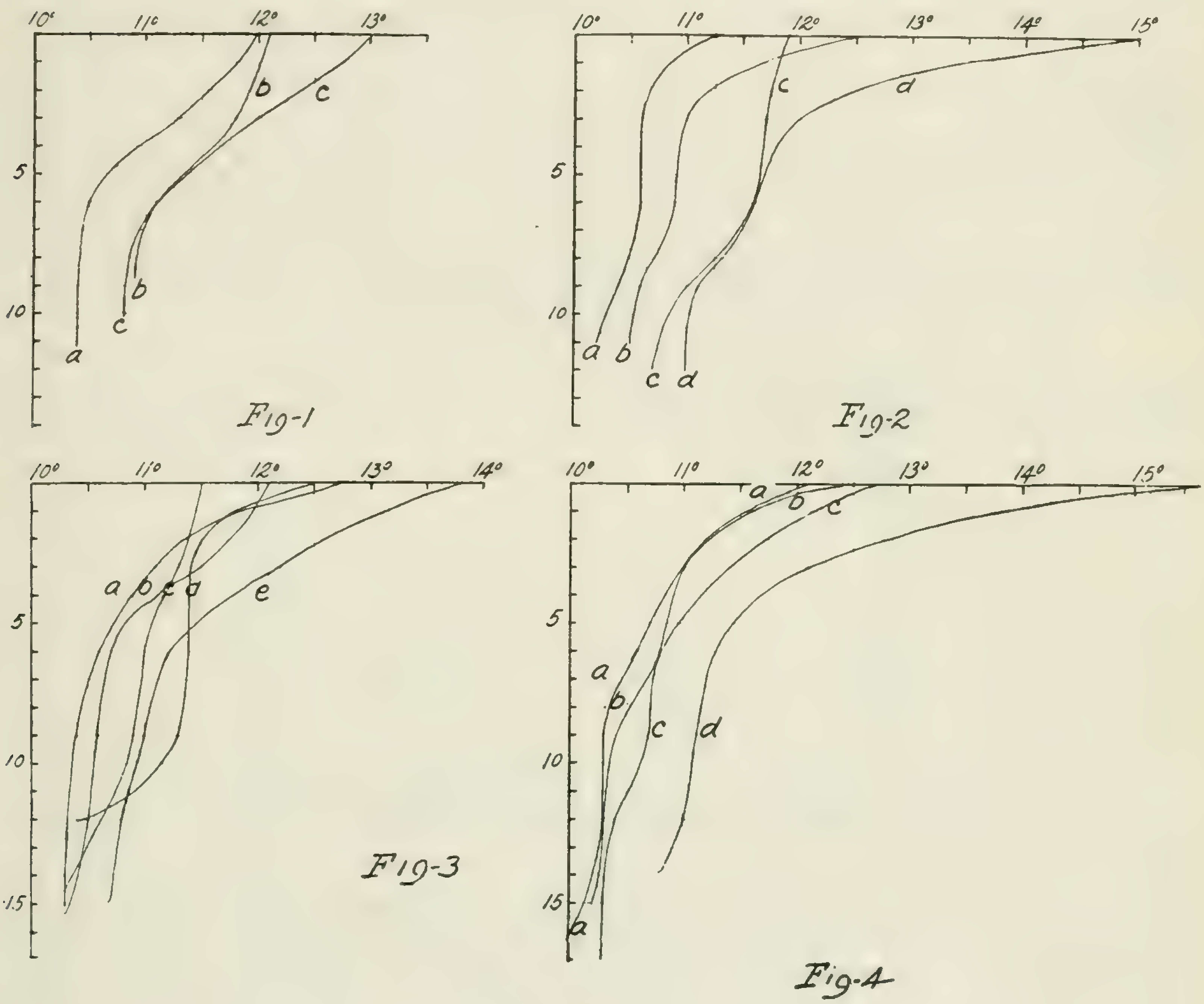
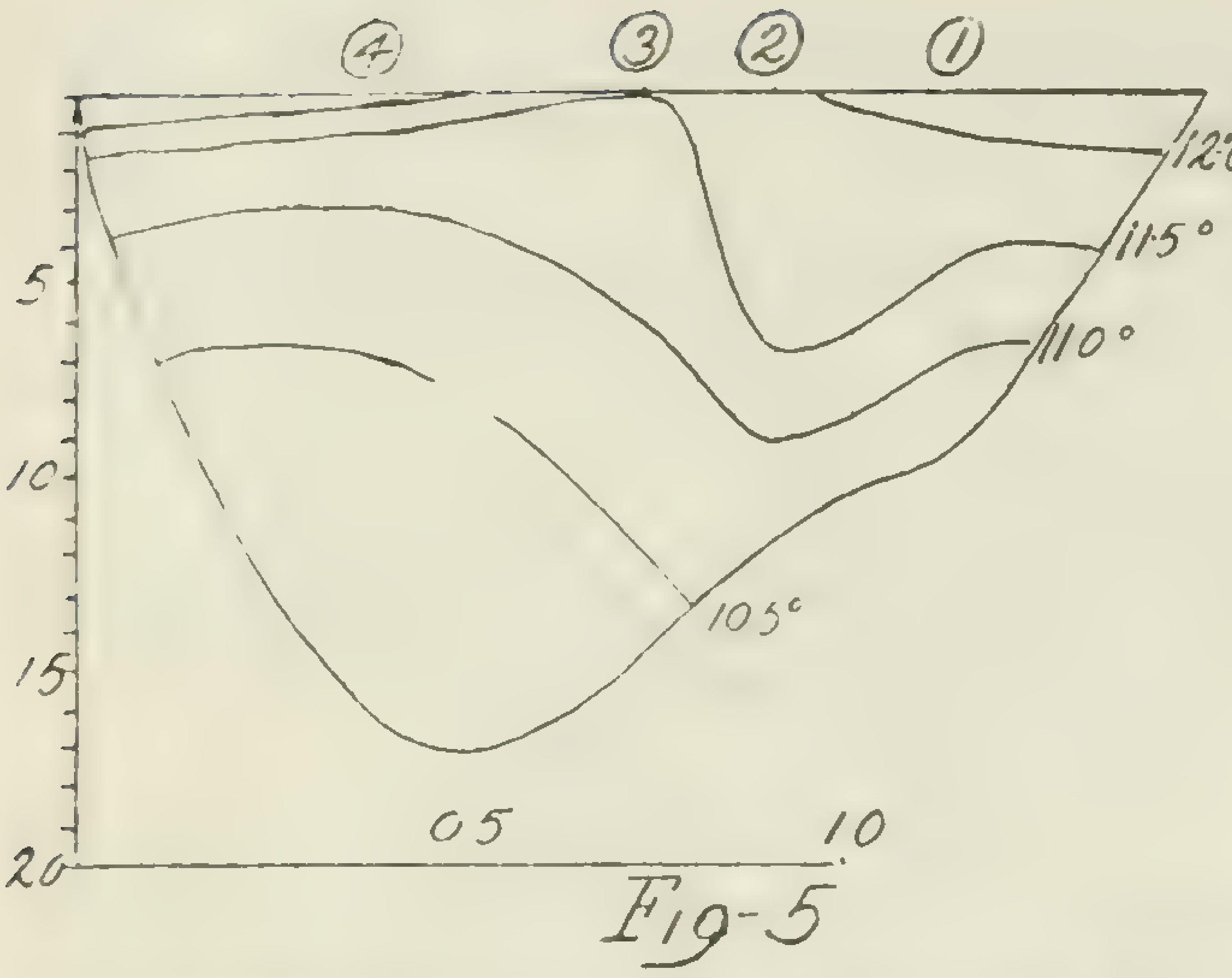


Fig. 1.—Temperature curves at Station 1: (a) Aug. 7, 1/4 ebb; Aug. 6, 1/2 flood; (c) Aug. 19, 1/6 ebb.
Fig. 2.—Temperature curves at Station 2: (a) Aug. 7, 1/4 ebb; (b) Aug. 4, ebb; (c) Aug. 6, 1/2 flood; Aug. 19, 2/3 ebb.
Fig. 3.—Temperature curves at Station 3: (a) Aug. 5, 2/3 ebb; (b) Aug. 7, 1/2 ebb; (c) Aug. 6, 2/3 flood; (d) Aug. 4, ebb; (e) Aug. 19, 1/6 ebb.
Fig. 4.—Temperature curves at Station 4: (a) Aug. 6, 2/3 flood; (b) Aug. 5, 2/3 ebb; (c) Aug. 8, 1/2 ebb; (d) Aug. 19, 1/8 flood.

Biological Station (figs. 1-4), the whole curve moves to the right, i.e., the temperature rises at all depths. The graphs also show that the whole of the water increases in temperature as the summer advances. It will be noted that the temperature falls most rapidly near the surface, as a rule, and in many cases least rapidly about mid-water. The graphs at several stations, however, show that this condition is reversed, the most rapid decrease in temperature occurring in mid-water. This is particularly noticeable at stations 1, 10, 12, 16, 17 and 18 (figs. 1, 12, 19, 22, 14 and 15), while some of the other curves suggest it. It is a noteworthy fact that this character



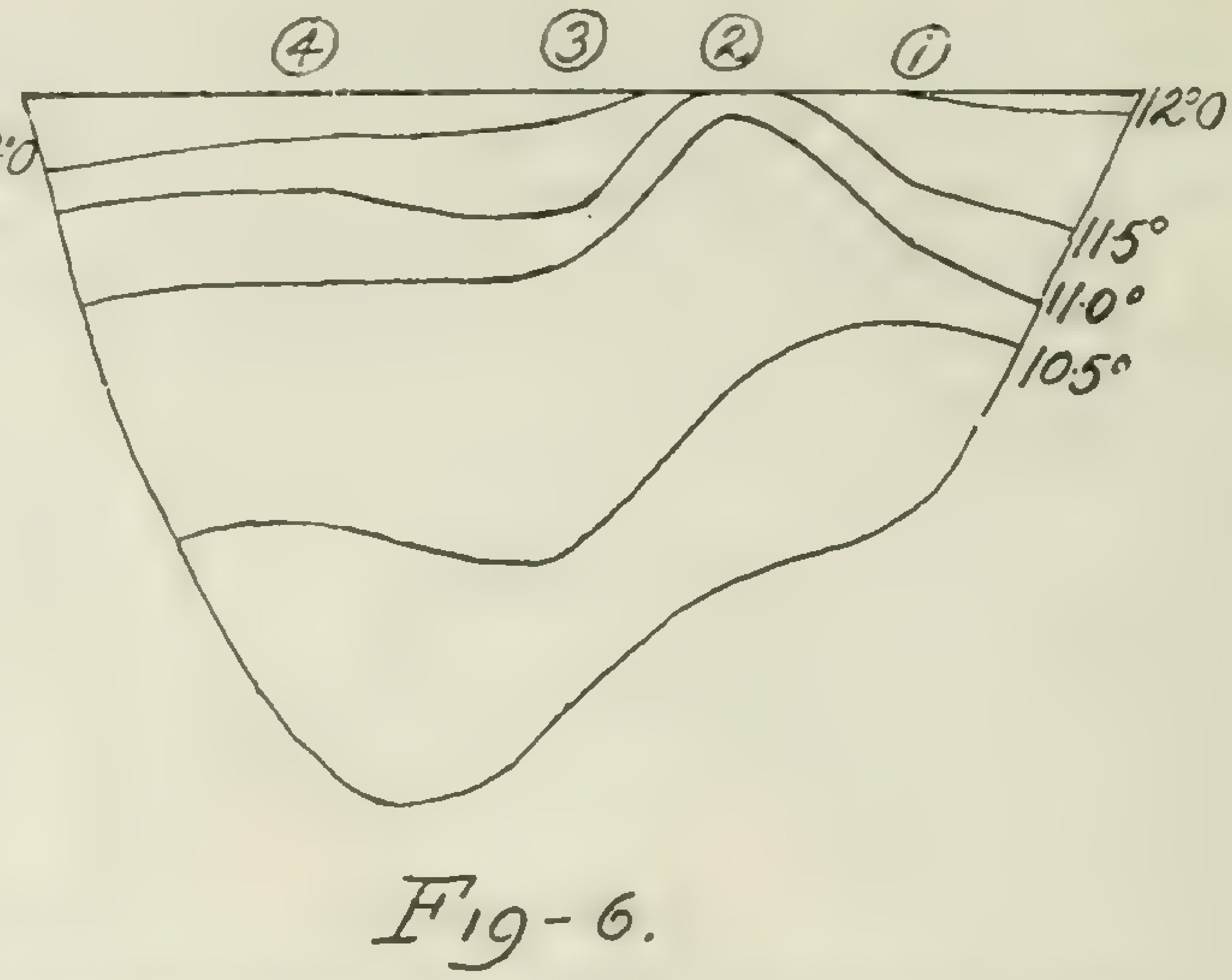
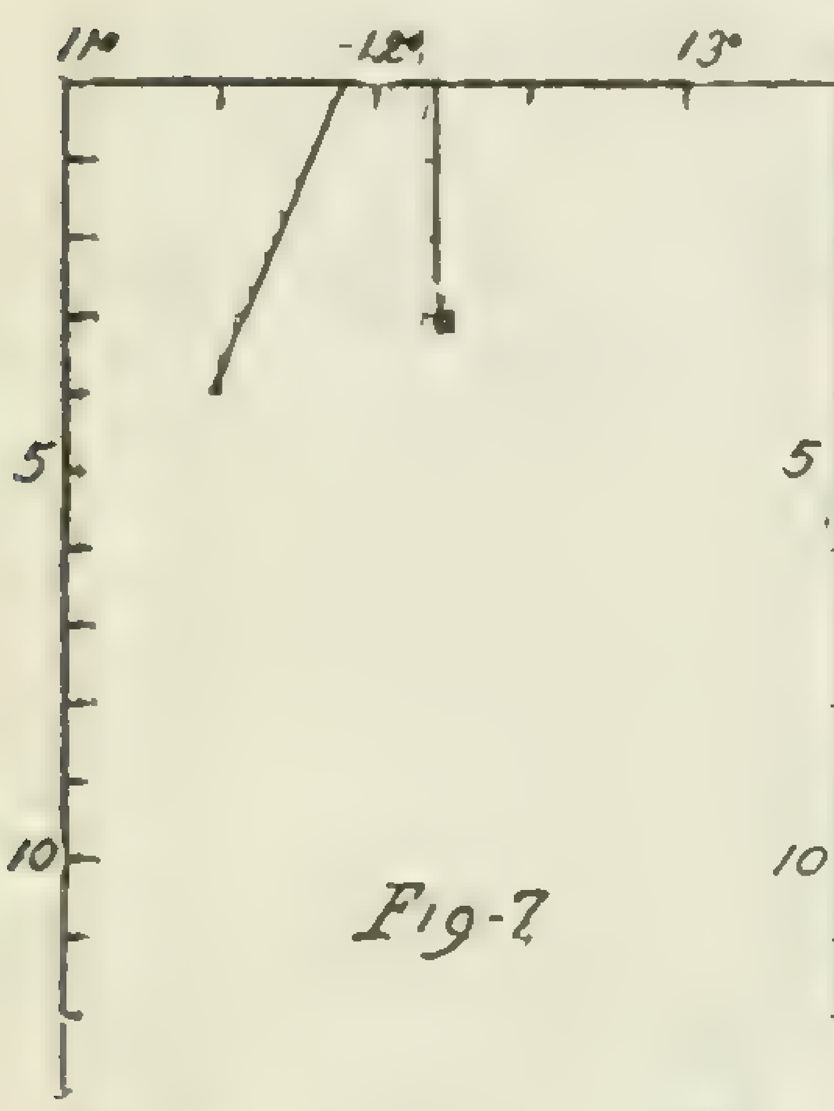
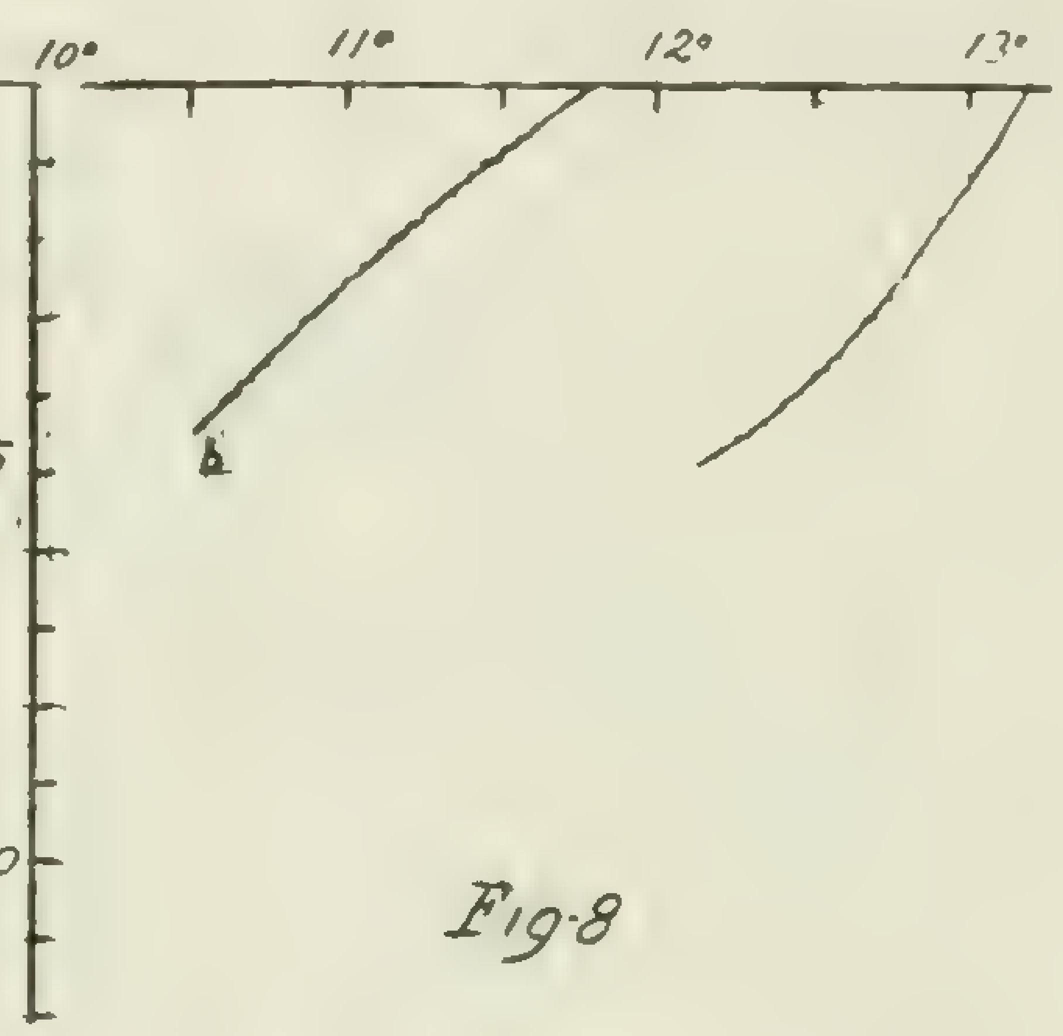
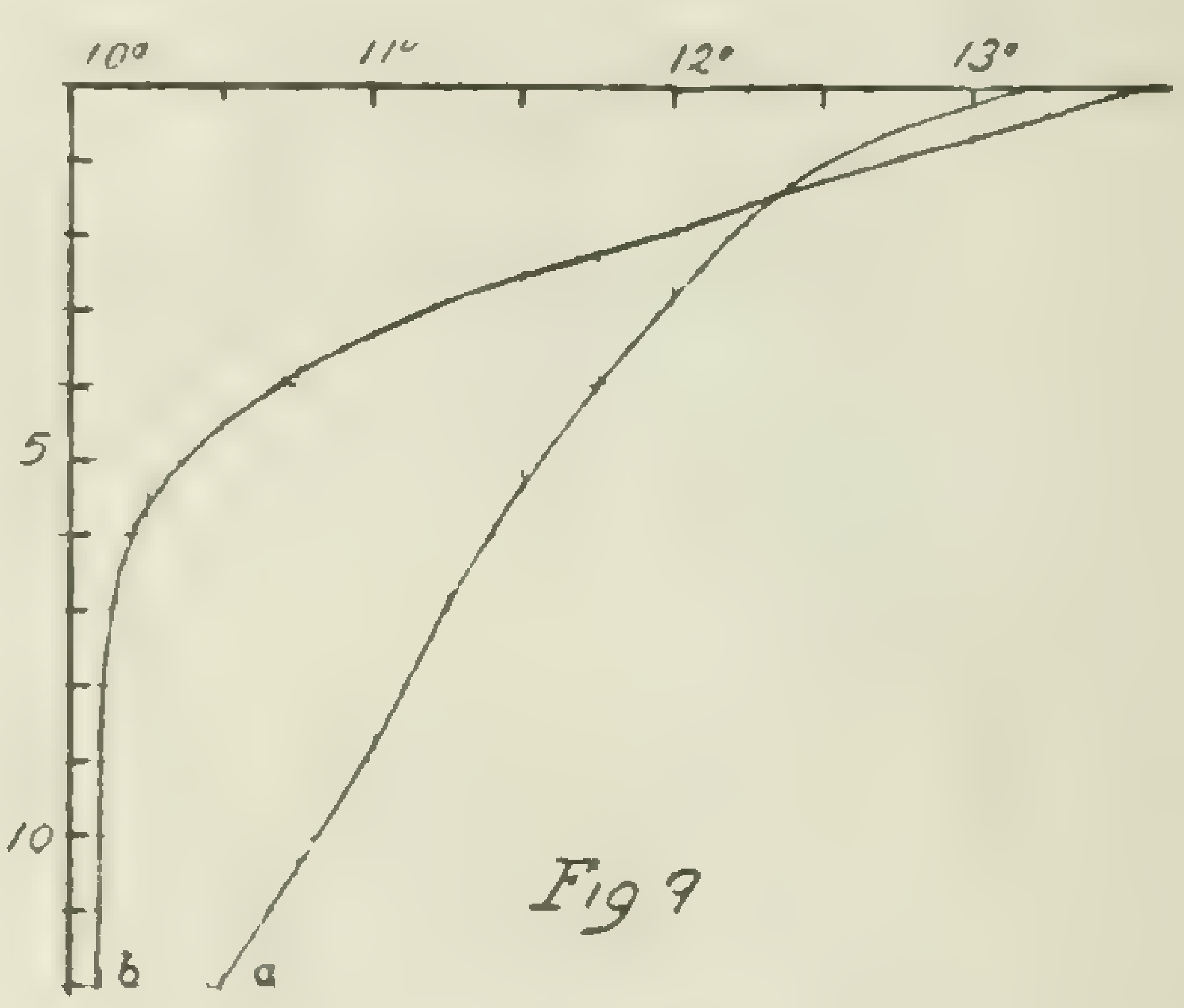
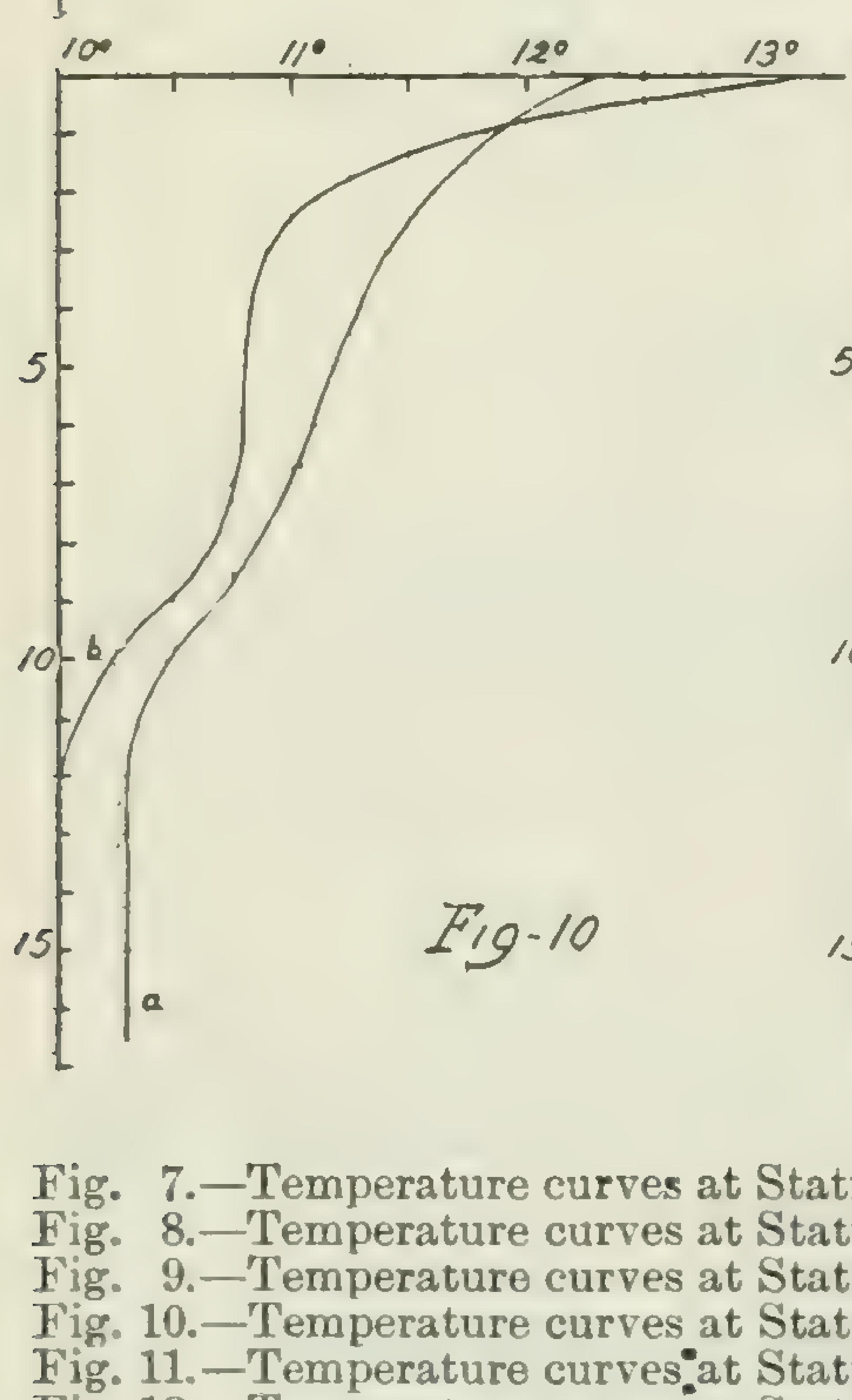


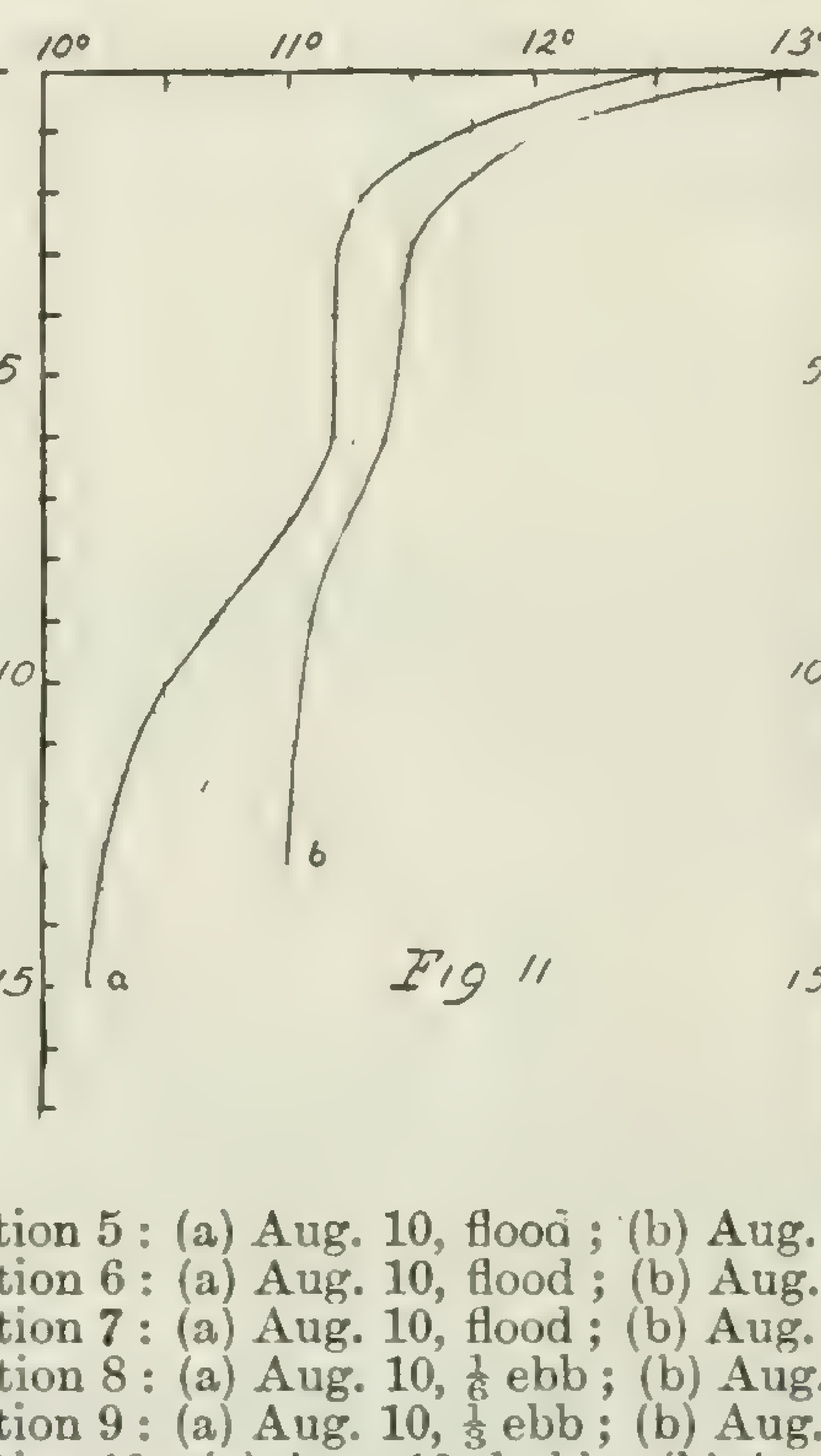
Fig. 5.—Profile section of the St. Croix River at the Biological Station. Aug. 6. Tide rising ($\frac{1}{2}$ to $\frac{3}{4}$ flood).
Fig. 6.—Profile section of the St. Croix River at the Biological Station, Aug. 7. Tide falling ($\frac{1}{4}$ to $\frac{1}{2}$ ebb).











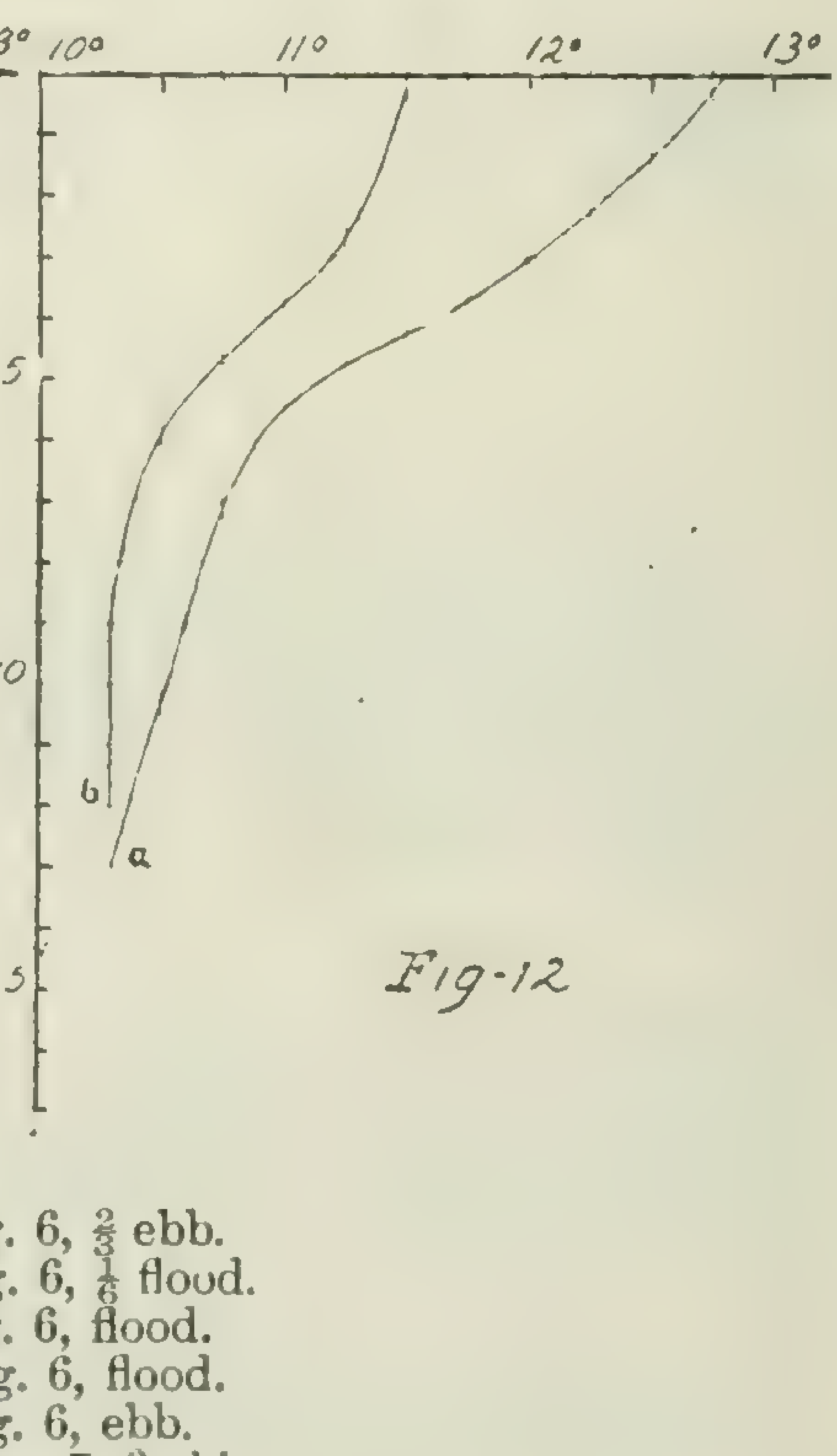


Fig. 7.—Temperature curves at Station 5 : (a) Aug. 10, flood ; (b) Aug. 6, $\frac{2}{3}$ ebb.
Fig. 8.—Temperature curves at Station 6 : (a) Aug. 10, flood ; (b) Aug. 6, $\frac{1}{6}$ flood.
Fig. 9.—Temperature curves at Station 7 : (a) Aug. 10, flood ; (b) Aug. 6, flood.
Fig. 10.—Temperature curves at Station 8 : (a) Aug. 10, $\frac{1}{6}$ ebb ; (b) Aug. 6, flood.
Fig. 11.—Temperature curves at Station 9 : (a) Aug. 10, $\frac{1}{3}$ ebb ; (b) Aug. 6, ebb.
Fig. 12.—Temperature curves at Station 10 : (a) Aug. 10. $\frac{1}{3}$ ebb ; (b) Aug. 7, $\frac{2}{3}$ ebb.

varies with the state of the tide, and with more data it would doubtless throw some light upon the tidal currents. It also appears that the temperature at the bottom at station 3 did not change with the tide, but rose as the season advanced.

The two isothermal sections of the St. Croix river at the Biological Station (figs. 5 and 6), taken at nearly opposite states of the tide upon succeeding days, show a most interesting change in the arrangement of the layers of water. It will be seen that with a rising tide (fig. 5), the warmer water is massed near the Canadian shore —the right hand side of the figure—while with a falling tide (fig. 6), the colder water is heaped up at almost exactly the same place, while the warmer water is spread out towards the United States bank.

The section of the river at St. Andrews (fig. 13) shows the same general arrangement of the water, showing that it extends down to that point. It also confirms the evidence of a tidal change, as it will be noted that the cold water is about the centre of the river, while the section represents observations taken between flood tide and one-third ebb—just the time when the other two diagrams would lead us to expect

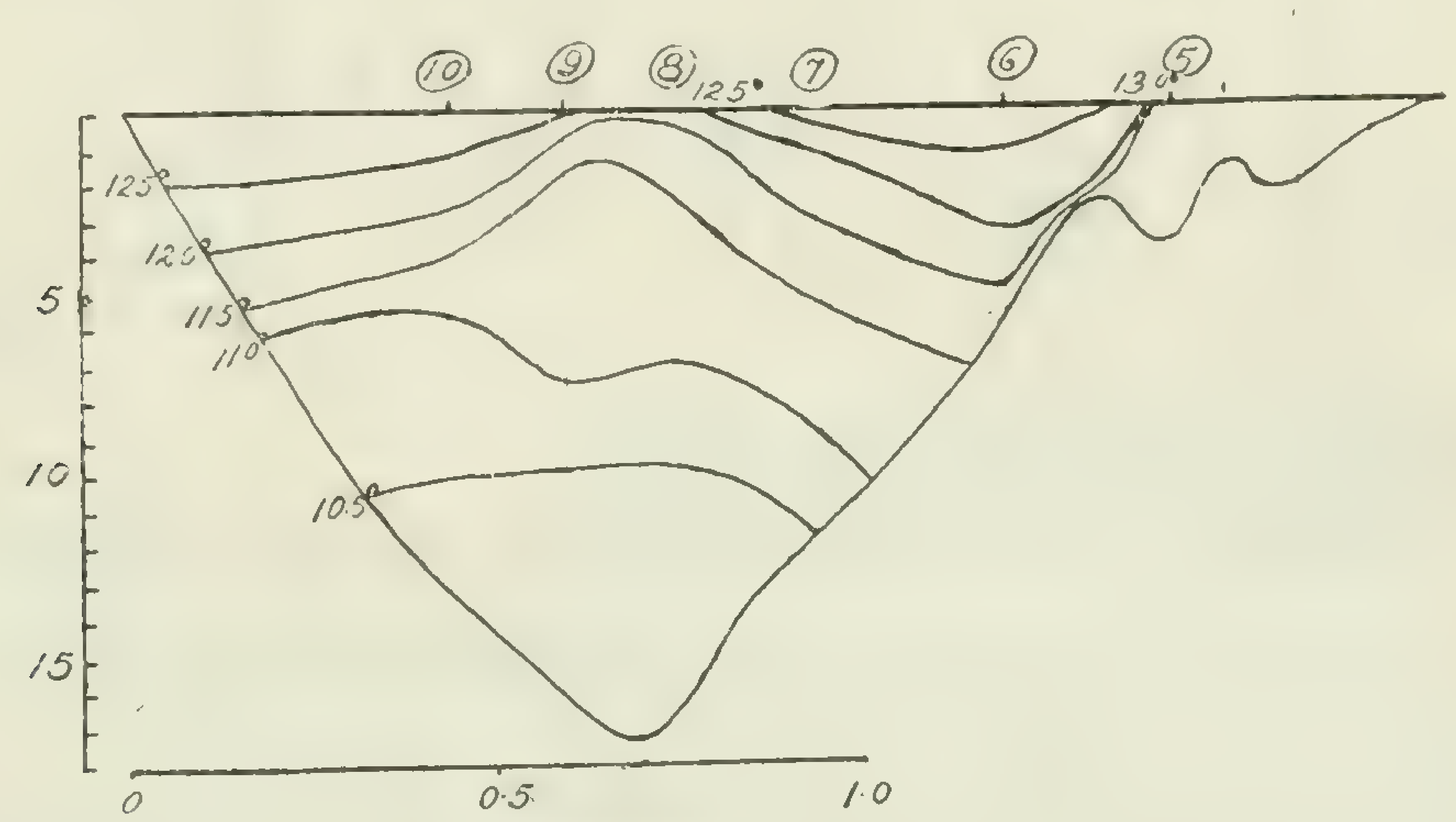


Fig -13

Fig 13.—Profile section of the St. Croix River at St. Andrews, Aug. 10. Tide beginning to fall (flood to ⅓ ebb).

the current of cold water to be crossing from the United States to the Canadian bank. This is a most interesting set of facts, which demands further investigation, as our present knowledge of the conditions in the St. Croix river and Passamaquoddy bay suggests no explanation. Apparently the great tidal currents in the bay swing round the current coming down the river, but just what these currents are and how they act we do not at present know.

It is also noteworthy that the warmest water does not pass through the channel between Navy island and the Canadian shore, the water there being comparatively cold, and the surface there being colder than at any other part of the section. Thus it would appear that while the surface and the bottom water both pass outside Navy island, some of the water from middle depths rises and runs through that channel. It may be that the rising tide has completely filled the narrow channel there with cold water from outside and forces the warmer water in the river to keep to the outer passage, where it flows over the cold water which advances to meet it.

The section at the Western passage (fig. 17) shows isotherms which, though more uniform than those in the St. Croix river sections, indicate the same general arrangement as that shown with a falling tide. In this section the tide is just beginning to rise, and the isotherms, as we would expect, appear to be flattening out and probably rising on the United States side, the left-hand side of the figure. The fact that

all the temperatures in this section are higher than those in the previous sections is to be accounted for by the fact that the observations were taken a fortnight later in the season. The fact that there is no cold water even at the bottom of this deep

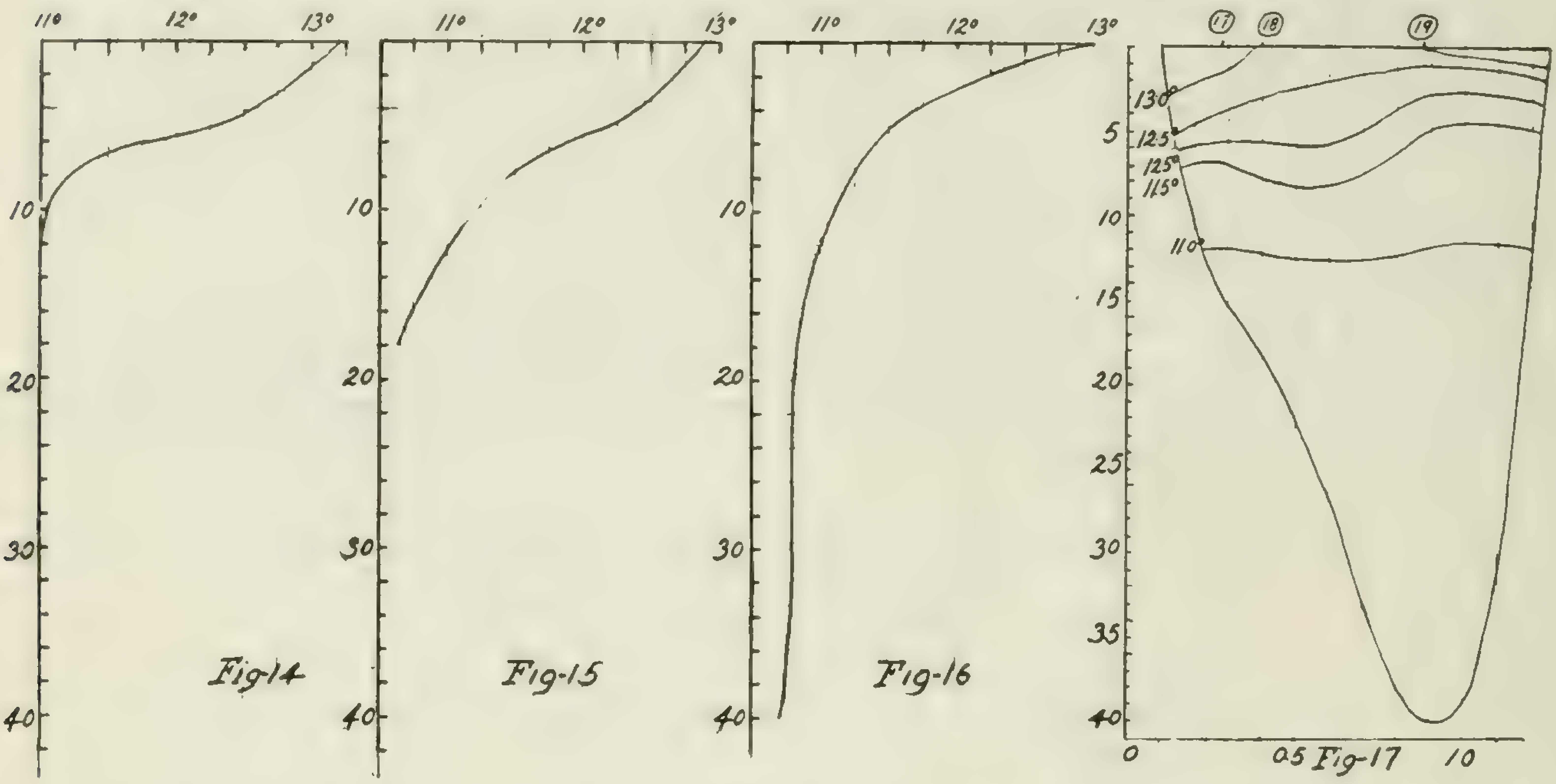


Fig. 14.—Temperature curve at Station 17. Tide ebb.
Fig. 15.—Temperature curve at Station 18. Tide ⅓ flood.
Fig. 16.—Temperature curve at Station 19. Tide ⅓ flood.
Fig. 17.—Profile section of the Western Passage, Aug. 20. Tide beginning to rise (ebb to ⅓ flood).

channel seems to indicate that it is entirely filled by water from the river and bay, which is in constant motion right to the bottom.

Turning now to the section of Passamaquoddy bay (fig. 23), we find the above conclusions with regard to the course of the warm water in the river confirmed. As

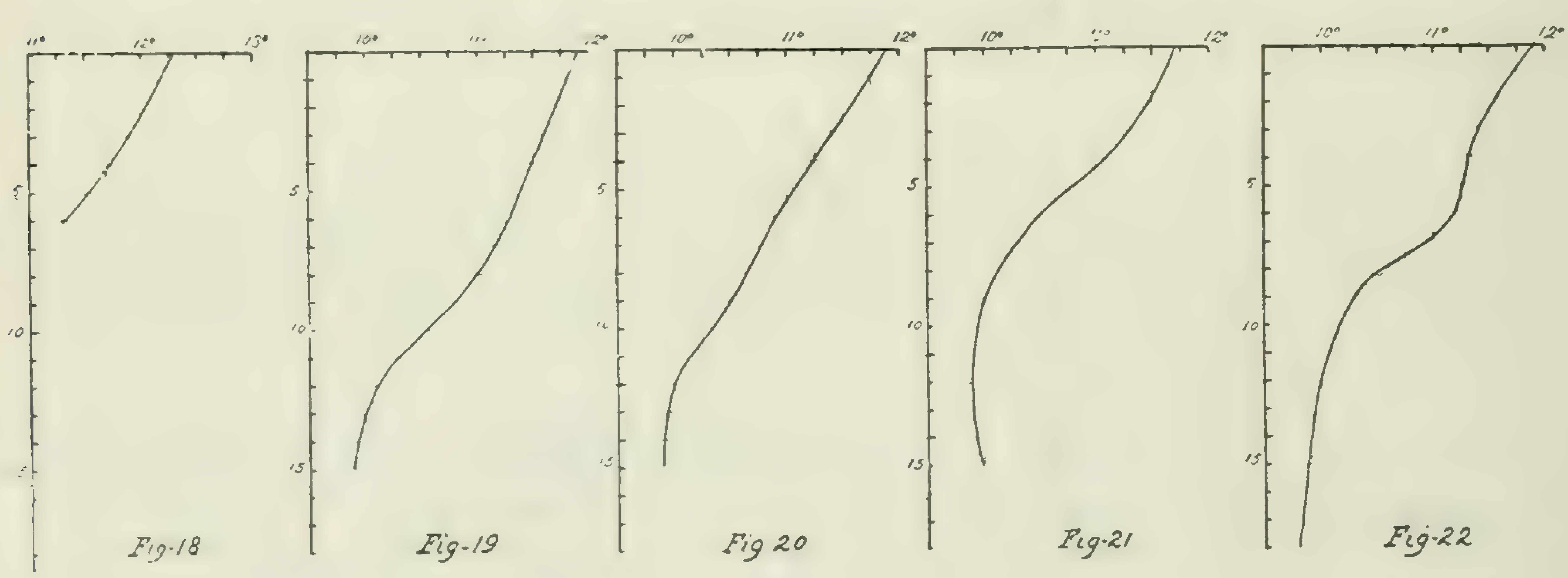


Fig. 18.—Temperature curve at Station 11. Aug. 5, ⅜ flood.
Fig. 19.—Temperature curve at Station 12. Aug. 5, ⅜ flood.
Fig. 20.—Temperature curve at Station 13. Aug. 5, ⅛ flood.
Fig. 21.—Temperature curve at Station 14. Aug 5, flood,
Fig. 22.—Temperature curve at Station 16. Aug. 5, ⅙ ebb.

in previous cases, the water in the centre is colder than near the sides, but it will be noticed that the warmest water appears at the mouth of the St. Croix river, i.e., at the extreme left of the diagram, while colder water than is found in any of the other sections, and much colder than appears in the Western passage, occurs in the deep

part near the right of the diagram, i.e., near Letite passage. Thus we may conclude that, while the warm water passes out through the Western passage, cold water from outside enters through Letite passage. This cold water does not appear in the section, but may be seen from the tables.

It is claimed by the fishermen that a current runs northeast along the north shore of Deer island from the Western passage. This probably meets the cold water entering at Letite passage and the two currents mingle and run out into the bay. A

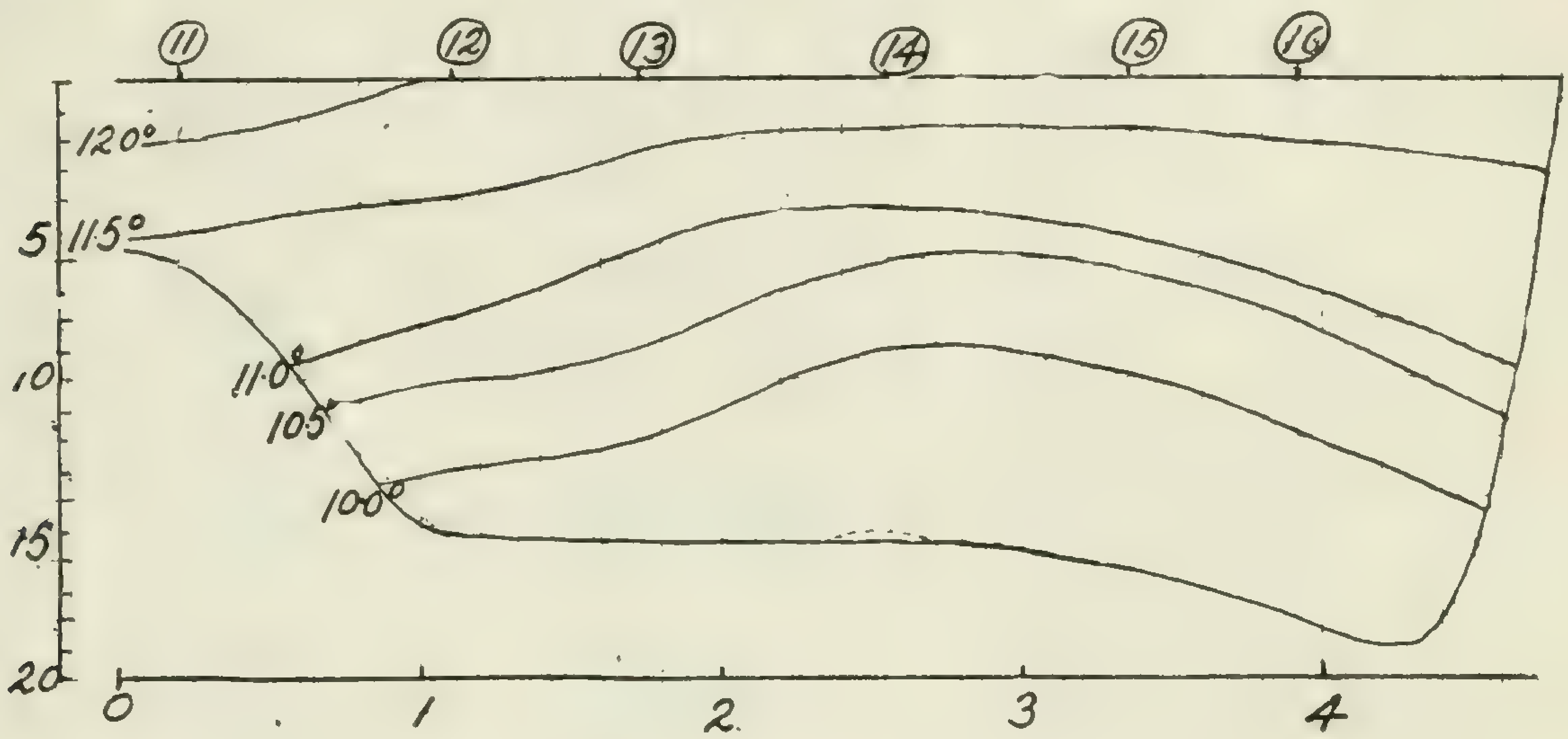


Fig 23

Fig. 23.—Profile section of Passamaquoddy Bay from Tongue Shoal Light to Deer Island beside Pendleton Island. Aug. 5. Tide $\frac{5}{8}$ flood to $\frac{1}{6}$ ebb.

little water at a slightly higher temperature appearing at the bottom at station 14 is probably due either to this current coming up from the Western passage, or to a small current running out from the mouth of the river. This water of higher temperature is indicated by a dotted line.

It is very unfortunate that sufficient data with regard to the densities to confirm these conclusions were not obtained, and that direct observations upon the currents could not be made, but it is felt that the work gives a foundation upon which further and more definite investigations may be based, either to confirm and extend the conclusions reached, or to demonstrate their error and provide the correct explanation of the conditions.

DATA of Sections of St. Croix River

Station.	Bottom.	Date.	Time.	Depth.	Tide.	Air Temp.
						°C.
1	Sand	Aug. 6	9 A.M.	9 F.	½ flood.	
		" 7	2 P.M.	11 "	¼ ebb.	
		" 19	11.15 A.M.	10 "	⅙ ebb.	22·6
2	Sand	" 4	4.55 P.M.	11 "	Ebb.	
		" 6	9.15 A.M.	12.5 "	½ flood.	
		" 7	2 P.M.	12.5 "	¼ ebb.	
		" 19	1.15 P.M.	12 "	⅔ ebb.	27·3
3	Rock	" 4	5.42 P.M.	12.5 "	Ebb.	
		" 5	3.40 P.M.	15.7 "	⅔ ebb.	
		" 6	9.50 A.M.	14.5 "	⅔ flood.	
		" 7	3 P.M.	15.5 "	½ ebb.	
		" 19	2.45 P.M.	15 "	⅚ ebb.	26·5
4	Sand	" 5	3 P.M.	15.5 "	⅔ ebb.	
		" 6	10.25 A.M.	16 "	⅔ flood.	
		" 7	3.35 P.M.	17 "	½ ebb.	
		" 19	5.15 P.M.	14 "	⅙ flood.	23·5
5		" 6	4.20 P.M.	2.5 "	⅔ ebb.	
		" 10	2.30 P.M.	4 "	Flood.	21·4
6	Sand	" 6	11.10 A.M.	4.5 "	⅚ flood.	
		" 10	3 P.M.	5.5 "	Flood.	16·4
7	Mud	" 6	11.25 A.M.	11.5 "	Flood.	
		" 10	3.25 P.M.	12 "	Flood.	17·1
8	Fine sand	" 6	11.55 A.M.	17 "	Flood.	
		" 10	3.55 P.M.	16.5 "	⅙ ebb.	18·0
9		" 6	4.45 P.M.	13 "	Ebb.	
		" 10	4.35 P.M.	15 "	⅓ ebb.	18·0
10	Mud	" 7		12 "	⅔ ebb.	
		" 10		13 "	⅓ ebb.	19·0
11	Rock	" 5	9.20 A.M.	6 "	⅔ flood.	
12	Mud	" 5	9.50 A.M.	15 "	⅔ flood.	
13	Mud	" 5	10.25 A.M.	15 "	⅚ flood.	
14	Mud	" 5	11.10 A.M.	15 "	Flood.	
16	Rock	5 5	12·10 P.M.	18 "	⅙ ebb.	
17		" 20	5 P.M.	14.5 "	Ebb.	21·4
18		" 20	6 P.M.	18 "	⅙ flood.	18.5
19		" 20	7 P.M.	41.5 "	⅓ flood.	16·5

and Passamaquoddy Bay.

1 Fath.	3 Fath.	6 Fath.	9 Fath.	12 Fath.	15 Fath.	18 Fath.
°C.	°C.	°C.	°C.	°C.	°C.	°C.
12·1	11·8	11·1	10·9	....	....	
12·0	11·3	10·5	10·4	10·4	....	
13·0	12·0	11·1	10·8	....	....	
12·5	11·0	10·9	10·6	10·5	....	
11·9	11·7	11·6	11·0	10·7	....	
11·3	11·6	10·6	10·4	10·2	....	
15·0	12·0	11·6	11·1	11·0	....	
12·5	11·4	11·4	11·3	10·4	....	
12·7	11·1	10·6	10·4	....	10·3	
11·5	11·3	11·0	10·9	10·6	10·3	
12·1	11·5	10·7	10·6	10·5	10·3	
13·8	12·2	11·2	11·0	10·8	10·7	
12·5	11·0	10·8	10·4	10·3	10·2	
12·1	11·0	10·6	10·3	10·3	10·0	
12·7	11·4	10·8	10·7	10·4	10·3	10·3
15·6	12·1	11·3	11·0	11·0	10·8	
12·2	12·2	....	....	....	....	
11·9	11·5	....	....	....	....	
11·8	10·9	10·5	....	....	....	
13·2	12·7	11·8	....	....	....	
13·6	11·2	10·2	10·1	10·1	....	
13·2	12·2	11·4	11·0	10·5	....	
13·3	10·9	10·8	10·5	10·0	10·0	10·0
12·3	11·4	11·1	10·7	10·3	10·3	
13·1	11·5	11·4	11·1	11·0	....	
12·5	11·2	11·2	10·7	10·3	10·2	
11·5	11·2	10·5	10·3	10·3	....	
12·8	12·0	10·9	10·6	10·3	....	
1·23	11·9	11·3	....	....	....	
11·9	11·6	11·3	10·8	10·1	9·9	
11·9	11·4	10·9	10·5	10·0	9·9	
11·7	11 3	10·5	10·0	9·9	10·0	
11·9	11·4	11·2	10·3	10·0	9·9	9·8
13·2	12·8	11·8	11·1	11·0	....	
Surf.	**5 Fath.**	**10 Fath.**	**15 Fath.**	**20 Fath.**	**30 Fath.**	**40 Fath.**
°C.	°C.	°C.	°C.	°C.	°C.	°C.
12·9	12·2	11·2	10·8	10·9	....	
13·0	11·5	11·1	11·0	10·8	10·8	10.7

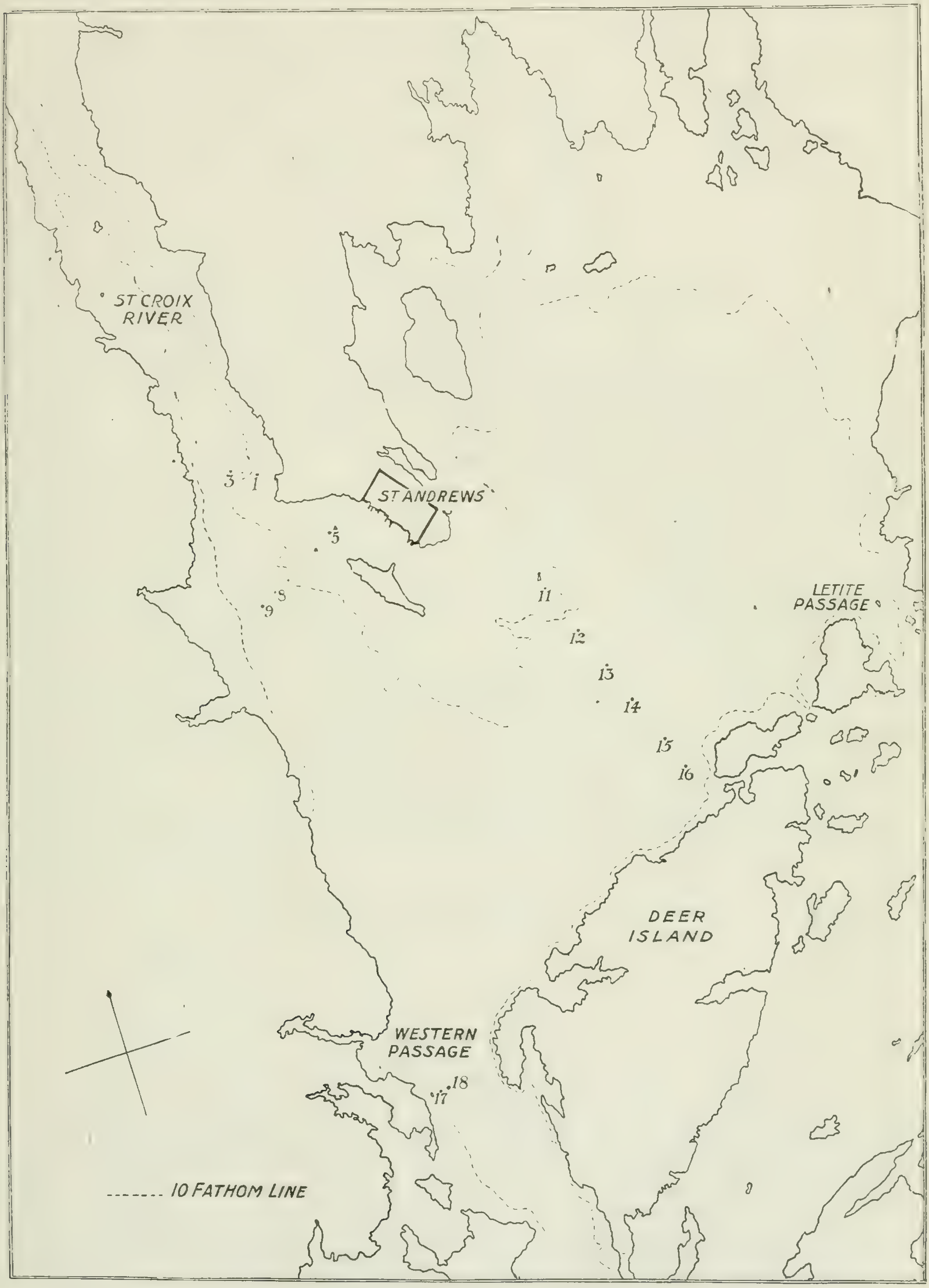
DENSITIES.

Station.	Date.	Time.	Depth.	Tide.	Surf.	3 F.	6 F.	9 F.	12 F.	15 F.	—
1	Aug. 19	11.15 A.M.	10 F.	$\frac{1}{3}$ ebb.	1·02391	1·02420	1·02431	1·02440	....	....	
2	" 19	1.15 P.M.	14 "	$\frac{2}{3}$ ebb.	1·02180	1·02393	1·02440	1·02449	1·02450	2·02451	
3	" 19	2.45 P.M.	15 "	$\frac{5}{6}$ ebb.	1·02211	1·02338	1·02429	1·02440	1·02444	....	
4	" 19	5.15 P.M.	14 "	$\frac{1}{6}$ flood.	1·02342	1·02420	1·02429	1·02457	....	....	
17	" 20	5 P.M.	14.5 "	Ebb.	1·02444	1·02450	1·02471	1·02464	1·02471	....	
					Surf.	5 F.	10 F.	15 F.	20 F.	30 F.	40 F.
18	Aug. 20	6 P.M.	18 F.	$\frac{1}{6}$ flood.	1·02438	1·02482	1·02483	1·02495	1·02483	....	
19	" 20	7 P.M.	41.5 F.	$\frac{2}{3}$ flood.	1·02444	1·02468	1·02485	1·02476	1·02476	1·02479	1·02478

For purposes of comparison, the data recorded by Copeland in 1910 for four stations near stations established this summer are here appended, although it has not been found possible to locate his stations exactly.

Copeland's Station.	Near Station.	Date.	Tide.	Surface.	5 F.	10 F.	15 F.	30 F.
				°	°	°	°	°
9	3	July 7, 1910	Ebb.	9·9 1·0234	9·1 1·0235	6·17 1·0234	....	
....	....	" 8, 1910	Flood.	10·7 1·0227	9·1 1·0235	9·0 1·0235	8·7	
....	....	" 7, 1910	$\frac{1}{6}$ ebb.	10·1 1·0234	9·1 1·0235	9·0 1·0234	....	
43	13	" 15, 1910	Ebb.	12·3 1·0235	9·3 1·0235	8·9 1·0235	8·8	
....	....	" 31, 1910	Flood.	15·0 1·023	10·7 1·022	15·4 1·0235	9·7	
41	16	" 30, 1910	Ebb.	10·4 1·0235	10·8		....	
17	17–18	Aug. 21, 1910	$\frac{2}{3}$ flood.	13·1 1·022	11·0 1·0237		.... 1·0241	11·1

Hydrography St. Croix R., etc. E. Horne Craigie.



XVI.

A HYDROGRAPHIC SECTION OF THE BAY OF FUNDY IN 1914.

By E. Horne Craigie, *University of Toronto.*

(With 1 Chart and 5 Figures.)

In addition to the hydrographic investigations in the St. Croix river and Passamaquoddy bay, which have been described in a separate report, it was felt that much might be gained from a similar investigation of the Bay of Fundy itself. Under the existing conditions very much of such work could not readily be carried on, and lack of time necessarily made the observations very limited, but during the last week of August a cruise was made across to St. Mary's bay, Nova Scotia, on which it was found possible to make sufficient observations to form one complete section across the bay. To add to the value of the work, one of the members of the staff took plankton samples at each station. A few observations of the surface temperature were also made between the stations. These are recorded in the table of data obtained, but were not sufficient for any deduction to be made from them.

The apparatus used in this work was exactly the same as that which has already been described in the report on the work in the St. Croix river and Passamaquoddy bay, as were all the methods employed. The weight used for sounding was twenty-two pounds. On account of the depth of the water, observations were made only at 10-fathom intervals instead of at 3-fathom intervals as was done in the previous investigation, except at the two deeper stations in the Western passage.

Temperature curves for each station and an isothermal section of the bay have been constructed. For convenience of comparison the section has been drawn upon the same scale as the accompanying map, upon which the stations are shown.

The stations were established upon a straight line drawn from East Quoddy head, Campobello island, to Boars head, Petit passage, Long island, Nova Scotia, and were located as follows:—

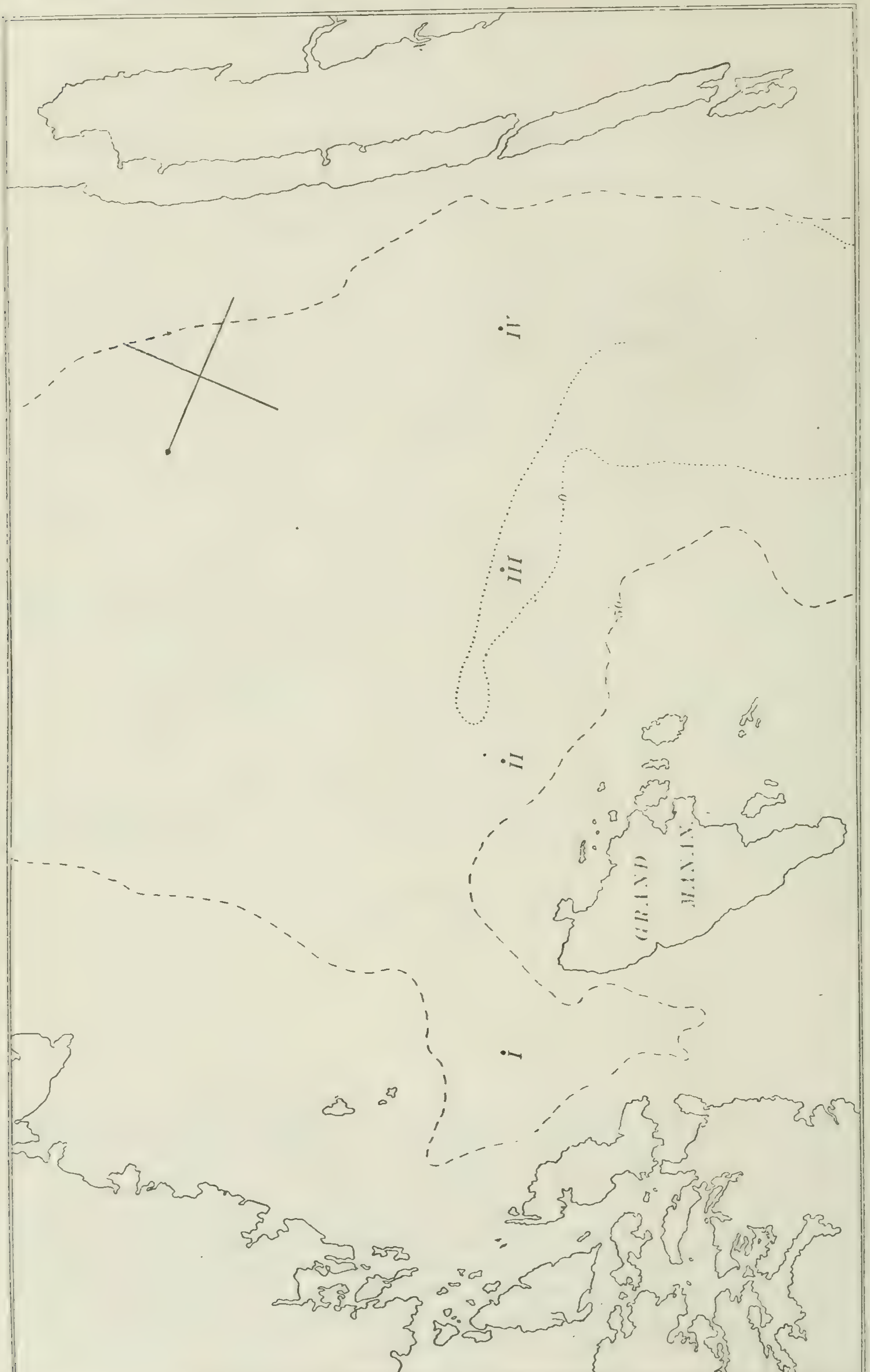
Section	I — 7	miles	from	East	Quoddy	head.
"	II —19	"	"	"	"	
"	III —27	"	"	"	"	
"	IV —37	"	"	"	"	
"	III-a—30¾	"	"	"	"	
"	III-b—33¼	"	"	"	"	
"	IV-a—40	"	"	"	"	

The distances are geographical miles. The points were found by the use of a log.

The 50 fathom and 100 fathom lines have been inserted upon the map, which thus gives an idea of the conformation of this part of the bay and shows how the stations were established so as to obtain as complete a section as possible, showing conditions in the various parts. Station 1 is in the Grand Manan channel, which will be noticed to rise to less than 50 fathoms a little further out, while station III has been placed so as to show the conditions in the deepest part, where the depth is over 100 fathoms.

The temperature curves (see figure) are interesting in that they show a marked resemblance between stations II, III, and IV, while station I in the Grand Manan channel is distinctly different. Considerable areas of the same, or nearly the same,

Bay of Fundy Hydrography. E. Horne Craigie.



temperature occur at stations III and IV. These are even more marked in the section than in the graphs. The occurrence of such areas about the mouth of the bay of Fundy has been recorded by Bigelow,* who attributes them to the vertical mixing of the water by the strong tidal currents. A stream of water of slightly higher temperature than that around it indicated by a dotted line, appears near the bottom at station II. As the difference is small, the corrections have been made and the second decimal is given for the temperatures at this point. The actual limits of this area, as indicated by the line, are, of course, arbitrary and may be quite wrong, being founded upon the reading obtained at a single point only. It seems, however, that the position indicated is a probable one. It will be noticed that the coldest water is not in the deepest part of the channel, but on the slope coming down from Grand Manan. There is no marked difference between temperatures upon the two sides of the bay, the water towards the Nova Scotia shore (the right of the diagram) being slightly warmer on the whole.

The densities were determined by bringing the samples to a temperature of 15·56° C. in a water bath and then reading the density from the hydrometer. The results, however, are so irregular that nothing can be deduced from them. As I am not satisfied as to the reliability of our apparatus, I simply give the figures obtained for what they are worth. In each case the density is recorded under the temperature at the same point.

In conclusion, I wish to thank Dr. Mavor for the constant direction and assistance which he has given me in all the work recorded in these reports.

---

* "Oceanographic Cruises of the United States Fisheries Schooner Grampus, 1912-1913," by Henry B. Bigelow, in "Science," N.S., Vol. XXXVIII, No. 982, pages 599-601, October 24, 1913.

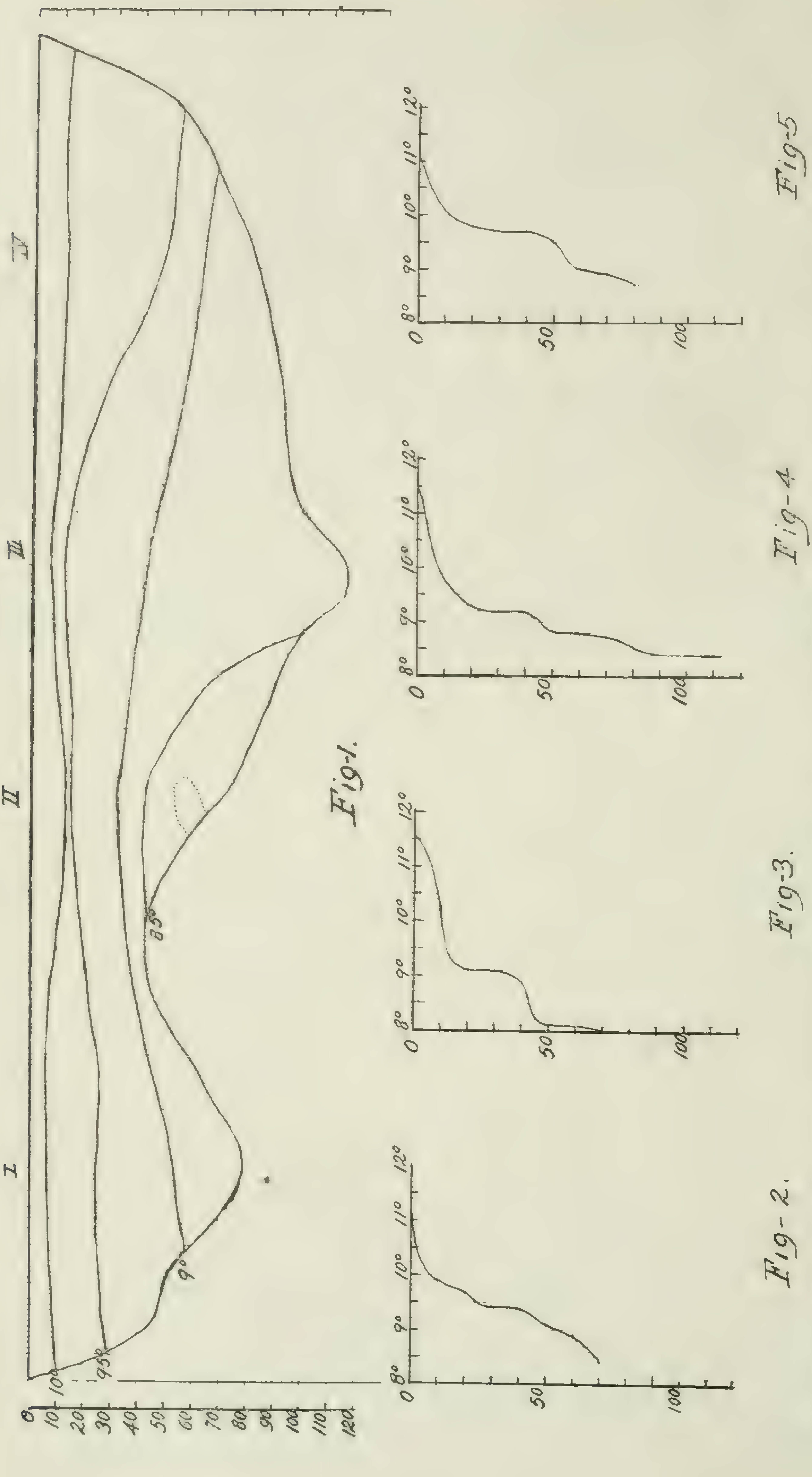


Fig. 1. Profile section of the Bay of Fundy from East Quoddy Head to Petit Passage. Fig. 2. Temperature curve at Station I. Fig. 3. Temperature curve at Station II. Fig. 4.—Temperature curve at Station III. Fig. 5.—Temperature curve at Station IV.

DATA of Section of Bay of Fundy.

Station.	I.	II.	II.	III.	III.	IV.	IV.	IIIa.	IIIb.	IVa.
Date.	August 27.	August 27.	August 29.	August 27.	August 29.	August 29.	August 27.	August 29.	August 27.	August 29.
Time.	11.20 am. 12.20 p.m.	2.05. 2.55 p.m.	12.40 p.m.	3.55 5.15 p.m.	11.35 a.m.	9.30 a.m. 10.20 a.m.	7.05 p.m.	11.15 a.m.	6.30 p.m.	9.05 a.m.
Bottom	sand	mud	......	mud	......	sand & hard				
Depth	79 F.	71 F.	......	113 F.	......	81 F.				
Tide	1/3 flood	2/3 flood	1/6 ebb	flood	ebb	2/3 ebb	1/2 ebb	5/6 ebb	1/3 ebb	1/2 ebb
Wind	S.	S.W.	N.E.	S.W.	N.E.	N.E.	S.W.	N.E.	S.W.	N.E.
Air temperature	15·0°	13·5°	11·8°	15·2°	14·2°	13·2°	......	14·8°	......	14·6°
Surface temperature	11·2°	11·5°	14·2°	11·5°	12·1°	11·2°	11·3°	11·1°	11·1°	11·6°
density	1·02322	1·02393	......	......	......	1·02440				
10 F. temperature	9·9°	10·2°	......	9·8°	......	10·1°				
density	1·02382	1·02403	......	1·02425	......	1·02437				
20 F. temperature	9·7°	9·1°	......	9·3°	......	9·9°				
density	1·02397	1·02419	......	1·02429	......	1·02449				
30 F. temperature	9·4°	9·1°	......	9·2°	......	9·7°				
density	1·02401	1·02422	......	1·02429	......	1·02455				
40 F. temperature	8·4°	8·9°	......	9·2°	......	9·7°				
density	1·02419	1·02438	......	1·02420	......	1·02474				
50 F. temperature	9·1°	8·1°	......	8·8°	......	9·5°				
density	1·02434	1·02468	......	1·02452	......	1·02469				
60 F. temperature	8·9°	8·18°	......	8·8°	......	9·0°				
density	1·02423	1·02461	......	1·02483	......	1·02462				
70 F. temperature	......	8·05°	......	......	......	8·9°				
density	......	1·02480	......	......	......	1·02493				
75 F. temperature	8·4°	......	......	8·7°	......	......				
density	1·02420	......	......	1·02471	......	......				
80 F. temperature	......	......	......	......	......	8·7°				
density	......	......	......	......	......	1·02477				
90 F. temperature	......	......	......	8·4°						
density	......	......	......	1·02478						
100 F. temperature	......	......	......	8·4°						
density	......	......	......	1·02481						
112 F. temperature	......	......	......	8·4°						
density	......	......	......	1·02481						

XVII.

THE WATER AND IODINE CONTENTS OF SOME PACIFIC COAST KELPS.

By A. T. Cameron, M.A., B.Sc.

Assistant Professor of Physiology and Physiological Chemistry, University of Manitoba.

In a previous communication[1] I have dealt with the iodine content of a large number of marine species, both animal and vegetable, obtained near the Biological Station at Departure Bay, B.C., during the summer of 1914, while carrying out other work at the Station, I collected a considerable amount of kelp material, and this, with some rock-weed, has been subsequently analyzed in the Physiological Chemical Laboratory of the University of Manitoba. The results of these analyses follow. In all cases the material was allowed to drain for an hour before weighing. For the earlier weighings (May) an exact balance was not available, as is shown by the figures. The somewhat sticky surface of most of the Laminariaceæ prevents adherence of much sea-water, so that error from this source is very slight. The material was either at once heated to constant weight at 100° C., or preserved in absolute alcohol and subsequently so heated. Kendall's[2] method of iodine analysis was used. The material was obtained in Departure Bay, unless otherwise stated. Similar samples of those specimens marked with an asterisk were sent to Dr. F. T. Shutt for analysis of other constituents.

---

[1] Cameron, *Contributions to Canadian Biology,* Fasciculus I, 1911-1914, pp. 51-68, (Ottawa), 1915.

[2] Kendall, *Journ. Biol. Chem.,* XIX, p. 251, 1914.

Species.	Date obtained.	Weight fresh.	Weight dry.	Per cent Water.	Amount taken for Iodine Analysis.	Iodine found.	Per cent Iodine.	Remarks.
		gram.	gram.		gram.	gram.		
Laminaria bullata	June 6, 1914	3.525	0.474	86.55	0.432	0.001164	0.274	Samples of several young plants.*
	" 6, 1914	7.368	1.208	83.60	0.500	0.000863	0.173	Samples of several old plants.*
					0.500	0.000886	0.177	
							Mean 0.075	
Laminaria saccharina	" 6, 1914	3.350	0.419	87.49	0.405	0.000834	0.206	Samples of several young plants.*
	" 6, 1914	7.263	1.732	76.15	0.500	0.000394	0.079	Samples of several old plants.*
					0.500	0.000383	0.077	
							Mean 0,078	
Costaria turneri	" 6, 1914	7.613	0.933	87.75	0.500	0.000143	0.029	Samples of several plants.
Nereocystis lutkeana	May 26, 1914	1.25	0.08	94	.....	.....	.....	Frond
		0.65	0.01	94	.....	.....	.....	Float — One plant 0.7 feet long.
		0.60	0.06	90	.....	.....	.....	Stipe
	" 26, 1914	4.14	0.28	93.2	0.260	0.000708	0.272	Frond
		0.80	0.11	86.3	0.0266	0.000053	0.20	Float — One plant 1.3 feet long.
		0.69	0.07	90	0.0518	0.000158	0.305	Stipe
	" 26, 1914	4.95	0.32	93.6	0.296	0.000737	0.249	Frond
		1.35	0.08	94	0.0433	0.000083	0.19	Float — One plant 1.5 feet long.
		0.73	0.07	90	0.0723	0.000190	0.263	Stipe
	" 26, 1914	12.20	0.82	93.3	0.494	0.001272	0.257	Frond
		3.09	0.17	94.5	0.132	0.000133	0.086	Float — One plant 2.0 feet long.
		1.61	0.16	90	0.132	0.000406	0.305	Stipe
	" 26, 1914	23.7	1.74	92.7	0.494	0.001353	0.274	Frond
		2.50	0.14	94.4	0.113	0.000126	0.111	Float — One plant 2.1 feet long.
		1.65	0.14	91.5	0.128	0.000269	0.210	Stipe
	" 26, 1914	29.4	2.58	91.2	0.500	0.000870	0.174	Frond
		8.15	0.48	94.1	0.452	0.000725	0.145	Float — One plant 3 feet long.
		2.90	0.40	86.2	0.388	0.001045	0.269	Stipe
	" 26, 1914	46.1	2.45	92.5	0.500	0.001082	0.216	Frond (sample)
		16.2	1.06	93.5	0.500	0.001311	0.262	Float (whole) — One plant 6 feet long.
		13.5	1.65	87.8	0.500	0.001376	0.275	Stipe (whole)
	" 27, 1914	.....	.....	.....	0.500	0.001441	0.288	Frond
					0.500	0.000979	0.196	Float — Samples of one plant 11 feet long.
					0.500	0.001257	0.251	Stipe
		.....	.....	.....	0.500	0.000567	0.113	Frond — Samples of one plant 12 feet long.
					0.500	0.000292	0.058	Float

	June 10, 1914	7.196	0.581	91.93	0.500	0.001252	0.250	Frond	Samples of several full-grown plants.*
		7.355	0.447	93.92	0.425	0.000554	0.130	Float	
		6.536	0.826	87.36	0.500	0.000666	0.133	Stipe	
					0.281	0.000374	0.133		
							Mean 0.133		
		4.894	0.627	87.19	0.500	0.000734	0.147	Holdfast	
	July 8, 1914	...	...	...	0.500	0.000489	0.098	Frond	Samples of several full-grown plants from Belle Chain, 50 miles, S.E. of Departure Bay*
					0.500	0.000972	0.194	Float	
								Stipe	
	" 25, 1914	...	...	...	0.500	0.000391	0.078	Frond	Samples (preserved in formol) from off Haddington Id. off the N. Coast of Vancouver Id. From several plants.*
					0.462	0.000375	0.081		
							Mean 0.079		
					0.500	0.000834	0.167	Float	
					0.217	0.000362	0.167		
							Mean 0.167		
					0.500	0.000328	0.066	Stipe	
					0.533	0.000347	0.065		
							Mean 0.065		
Macrocystis pyrifera	" 23, 1914	...	...	...	0.500	0.001053	0.210	Frond	Samples of several plants obtained of Suquash, N. Coast of Vancouver Id.*
					0.500	0.000954	0.191		
							Mean 0.200		
					0.500	0.000818	0.164	Float	
					0.500	0.000873	0.175	Stipe	
					0.500	0.000827	0.165		
							Mean 0.170		
					0.500	0.001170	0.234	Holdfast	
Alaria tenuifolia	June 6, 1914	...	...	...	0.500	0.000137	0.027	A single plant	
Fucus furcatus (? inflatus)	" 10, 1914	8.118	2.540	68.71	0.500	0.000214	0.043	Samples of several plants.*	
					0.500	0.000211	0.042		
							Mean 0.042		
	Aug. 20, 1914	...	...	...	0.500	0.000086	0.017	All samples of several plants obtained at the same spot at different heights above low tide mark.	
	" 20, 1914	...	...	...	0.500	0.000077	0.015		
	" 20, 1914	...	...	...	0.500	0.000126	0.025		
					0.500	0.000152	0.030		
							Mean 0.027		
	" 20, 1914				0.500	0.000056	0.011		
Fucus evanescens	June 10, 1914	8.070	1.628	79.83	0.500	0.000144	0.029	Samples of several plants.*	
					0.500	0.000141	0.028		
							Mean 0.028		
	Aug. 20, 1914	...	...	...	0.500	0.000078	0.016	All are samples of several plants obtained at the same spot at different heights above low tide mark *	
					0.500	0.000096	0.019		
					0.500	0.000071	0.014		
					0.500	0.000090	0.018		
					0.500	0.000073	0.014		
							Mean 0.016		
					0.500	0.000057	0.011		

Using the figures given in the previous report, the following data are available for variations of iodine content with age in the same species growing under the same conditions.

Species.	Obtained August, 1913.	Obtained June, 1914.	Obtained August, 1914.
Laminaria bullata	0·060	0·270 (young plants) 0·175 (old plants)	
Laminaria saccharina	0·156 (small plant) 0·176 (medium sized)	0·206 (young plants) 0·078 (old plants)	
Fucus furcatus	0·015 (average)	0·042	0·017 (average)
Fucus evanescens	0·016 (average)	0·028	0·015 (average)

These figures show the effect of age and a distinct effect of period of year (this has already been pointed out by Scurti for *Sargassum* and *Cystoseira*). The data for *Nereocystis* confirm these variations. A determination of ash was carried out with one set of samples of *Nereocystis;* the results are only approximate since some inorganic salt was vaporized before the carbon was completely ignited.

Where obtained.	Date.	Length of plant.	Per cent Water.			Per cent Iodine.			Per cent Ash.		
			Frond	Float.	Stipe.	Frond	Float.	Stipe.	Frond	Float.	Stipe.
	1914.	Feet.									
Departure Bay	May 26	0 7	94	94	90						
	" 26	1·3	93·2	86·3	90	0·272	0·20	0·305			
	" 26	1·5	93·6	94	90	0·249	0·19	0·263			
	" 26	2·0	93·3	94·5	90	0·257	0·086	0·305			
	" 26	2·1	92·7	94·4	91·5	0·274	0·111	0·210			
	" 26	3	91·2	94·1	86·2	0·174	0·145	0·269			
	" 26	6	92·5	93·5	87·8	0·216	0·262	0·275			
	" 27	11	....	.....	......	0·288	0·196	0·251	44·5	49·9	29·1
	" 27	12	..	.....	...	0·113	0·058	.....			
	June 6	Full grown	91·9	93·9	87·4	0·250	0·130	0·133			
	Aug. 13	Small	....	.. ..	......	0·184	0·120	0·147			
	" 13	Full grown	.....	......	...	0·171	0·090	0 161			
	" 13	"	89·2	94·4	92·2	.....	..	......			
Protection Is.	" 13	Small	......	....	......	0·064	0·217	0·085			
	" 13	Full grown	.....	......	.....	0·130	0·108	0·046			
Breakwater Is	" 13	Small	......	...		0 160	0·011	......			
Belle Chain	July 7	Full grown	...	...	.. .	0·098	0·194	.....			
Haddington Is	July 25	"	......	.. ..	.....	0·079	0·167	0·065			

The specimens obtained near Haddington island were preserved in formol, and I have shown elsewhere that in such cases iodine is lost in the subsequent evaporation to the extent of about 10 per cent.

Careful examination of the above figures shows, in spite of the marked individual variation which is their most striking characteristic, that the percentage of iodine is almost always less and the percentage of water greater in the float than in either the fronds or stipe. The ash determinations show a similar difference. The iodine content in *Nereocystis* appears, on the average, to diminish with growth, the highest values for frond and stripe being obtained for the smallest plants. The water content of frond and stipe shows dimunition with age (this is especially true for the

stipe), while that of the float is very constant. There is therefore an evident and marked difference between the composition of the float and that of the stipe; to microscopic examination they appear very similar in structure.

From the fact that young plants of *Nereocystis* usually contain more iodine than full grown ones, it follows that plants obtained during early summer, when the majority are not full grown, will give a greater average yield of iodine for the same weight, than plants obtained later in the year. (The total bulk of the plant increases rapidly, however, during the final stages of growth, so that with a lesser average content, full grown plants will yield a greater quantity of iodine. For harvesting for commercial purposes, also, *Nereocystis,* for various reasons set forth in an earlier report, should not be cut before July.)

Comparison of the figures given for full grown plants of *Nereocystis* with those given by other observers for the same species from other localities does not reveal any differences more marked than those in the last table above, and does not give any definite evidence that latitude is a factor in iodine content as has sometimes been suggested.

University of Manitoba,
June 30, 1915.